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Science Primers

PHYSICAL GEOGRAPHY

BY

SIR ARCHIBALD GEIKIE
F.R.S., D.C.L. ; F.R.Sc. ; LL.D.
Director-General of the Geological Survey of the United Kingdom and formerly Murchison Professor of Geology and Mineralogy in the University of Edinburgh

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PREFACE.

THIS little work was written with the object of showing that the teaching of science may be based on practical lessons taken from the common phenomena of everyday experience, and that to stimulate habits of observation among pupils is of infinitely higher present and future value than to load their memories with facts, often ill understood, and figures, painfully remembered. Since its publication in 1873, the issue of successive large impressions of the book in this country and in America, its translation into most European languages, and its introduction as a school-book on the Continent, encourage the hope that it has in some measure fulfilled its original design. It has now again been thoroughly revised and brought abreast of the onward progress of science.

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SCIENCE PRIMERS.

PHYSICAL GEOGRAPHY.

INTRODUCTION.

1. Let us suppose that in summer-time a party of young people, of whom you are one, have fixed upon a certain day for a holiday ramble into the country. Some are to gather wild flowers, some to collect pebbles, and some are going with no very definite aim beyond love of the holiday and of any sport or adventure which it may bring with it. Soon after sunrise on the eventful day you are all awake, and great is your delight to find the sky clear and the sun shining. It is arranged, however, that you do not start until after breakfast-time, and meanwhile you busy yourselves in getting ready all the baskets, sticks, and other gear of which you are to make use during the day. But the brightness of the morning begins to fade. The few clouds that were to be seen at first have grown into large heavy masses, and seem evidently gathering together for a

storm. And sure enough, ere breakfast is well over, the first ominous big drops begin to fall. You cling to the hope that it is only a shower that will soon be past, and you go on with the preparations for the journey. But the rain shows no symptom of soon ceasing. The big drops come down thicker and faster; little pools of water begin to form in the hollows of the road, and the window-panes are now streaming with rain. With sad hearts you have to give up all hope of holding your excursion to-day.

2. It is no doubt very tantalising to be disappointed in this way, when the promised pleasure was on the very point of becoming yours. But let us see if we cannot derive some compensation even from the bad weather. Late in the afternoon the sky clears a little, and the rain ceases. You are glad to get outside again, and so we all sally forth for a walk. Streams of muddy water are still coursing along the sloping roadway. If you will let me be your guide, I would advise that we should take our walk by the neighbouring river. We wend our way by wet paths, where every tree and hedgerow are still dripping with moisture, until we gain the bridge, and see the river right beneath us. What a change this one day's heavy rain has made! Yesterday, perhaps, you could almost have counted the stones, in at least the shallower places, so small and clear was the current. But look at it now! The water fills the channel from bank to bank, and rolls along swiftly. We can watch it for a little from the

bridge. As it rushes past, innumerable leaves and twigs are seen floating on its surface. Now and then a larger branch, or even a whole tree-trunk, comes down, tossing and rolling about on the flood. Sheaves of straw or hay, planks of wood, pieces of wooden fence,—sometimes a poor duck, unable to struggle against the current,—roll past us, and show how the river has risen above its banks and done damage to the farms higher up its course.

3. We linger for a while on the bridge, watching this unceasing tumultuous rush of water and the constant variety of objects swept down the channel. It was perhaps almost worth while to lose the holiday for the sake of seeing so grand a sight as this angry and swollen river, roaring and rushing with its full burden of dark water. Now, while the scene is still fresh before us, let us ask ourselves a few simple questions about it, and you will find perhaps additional reasons for not regretting the failure of the promised excursion.

4. In the first place, where does all this added mass of water in the river come from? You say it was the rain that brought it. Well, but how should it find its way into this broad channel? Why does not the rain run off the ground without making any river at all?

5. In the second place, where does the rain come from? In the early morning the sky was bright, then clouds appeared, and after that came the rain. You answer that it was the clouds that supplied the

rain. But whence come the clouds, and how do they gather rain and let it descend upon the earth?

6. In the third place, what is it which causes the river to rush on in one direction more than another? When the water was low, and one could, perhaps, almost step across the channel on the stones and gravel, the current, small though it might be, was still quite perceptible. One could see that the water was moving along the channel, always from the same quarter. And now when the channel is filled with this rolling torrent of dark water, you see that the direction of the current is still the same. Can you tell why this should be?

7. Again, yesterday the water was clear—to-day it is dark and discoloured. We take a little of this dirty-looking water home with us, and let it stand all night in a glass. To-morrow morning we shall find it clear, while a layer of fine mud will have sunk to the bottom of the glass. If we shake the glass and stir up the mud the water becomes dirty, as it was in the river. It is mud, therefore, which discolours the swollen river. But where did this mud come from? Plainly, it must have something to do with the heavy rain and the flooded state of the stream.

8. Well, this river, whether shallow or in flood, is always moving onward in one direction, and the mud which it bears along is carried towards the same point whither the river itself is hastening. While we sit on the bridge watching the foaming water as

it eddies and whirls past, the question comes home to us—what becomes of all this vast quantity of water and mud?

9. Remember, now, that our river is only one of many hundreds which flow across this country, and that there are thousands more in other countries where the same thing may be seen which we have been watching to-day. They are all in continual motion, are flooded when heavy rains come, and carry more or less mud along with them.

10. As we walk homewards again, it may be well to put together some of the chief features of this day's experience. We have seen that sometimes the sky is clear and blue, with the sun shining brightly and warmly in it; that sometimes clouds come across the sky, and that when they gather thickly rain is apt to fall. We have seen that a river flows; that it is swollen by heavy rain; and that when swollen it may be very muddy. In this way we have learnt how close is the connection between the sky above us and the earth under our feet. In the morning it seemed but a little thing that clouds should gather overhead; and yet, ere evening fell, these clouds led by degrees to the descent of torrents of rain, the flooding of the river, the sweeping down of trees, fences, and farm produce; and it might even be to the destruction of bridges, the inundation of fields, villages, and towns, and a large destruction of human life and property.

11. Those who live in a large town and have no

opportunity of seeing country sights, naturally enough imagine that these things cannot have much interest for them, and that they have no chance of seeing with their own eyes how nature works. They are not, however, without their opportunities. For example, they may learn a great deal about rain and streams even in the streets of a town. A little of the rain caught in a plate is so much clear water. But as it courses along the gutters, how muddy it is! It has swept away the loose dust worn by wheels and feet from the stones of the street. Each gutter thus becomes like the flooded river. One can watch, too, how chips of straw, corks, bits of wood, and other loose objects lying in the street, are borne away, very much as the trunks of trees are carried by the river. Even in a town, therefore, we can observe how changes in the sky lead to changes on the earth.

12. If you think for a little, you will recall many other illustrations of the way in which the common things of everyday life are connected together. As far back as you can remember, you have been familiar with such things as sunshine, clouds, wind, rain, rivers, frost, and snow, and they have grown so commonplace that you never think of considering about them. You cannot imagine them, perhaps, as in any way different from what they are; they seem, indeed, so natural and so necessary that you may even be surprised when any one asks you to give a reason for them. But had you lived all your

life in a country where no rain ever fell, and were you brought to such a storm of rain as we have been watching to-day, would it not be very strange to you, and would you not naturally enough begin to ask the meaning of it? Or suppose that a boy from some very warm part of the world were to visit a country in winter, where he could see, for the first time, a shower of snow, and rivers solidly frozen over, would you be surprised if he showed great astonishment? If he asked you to tell him what snow is, and why the ground is so hard, and the air so cold, —why the streams and ponds have become crusted with ice,—could you answer his questions?

13. And yet these questions relate to very common everyday things. If you think about them you will learn, perhaps, that the answers are not quite so easily found as you had imagined. Do not suppose that because a thing is common, it can have no interest. There is really nothing so common as not to deserve our attention, and to reward us for trying to understand it.

14. In the following pages I propose to ask you to look at some of these common things. You must not think, however, that it is my wish merely to set certain lessons which must be learnt, and to give a list of names and figures which must be committed to memory. My object rather is to urge you to look around, and to think out as far as you can the meaning of what you see. I would fain have you not to be content with what is said in

this little book, or in other books, but rather to get into the habit of using your own eyes that you may see and understand what takes place in this wonderful world of ours. All around there is abundant material for this most delightful inquiry. No excursion you ever made in pursuit of mere enjoyment and adventure by river, heath, or hill, could give you more hearty pleasure than a ramble with eyes and ears alike open to note the lessons to be learnt from every day and from every landscape. Remember that besides the printed books which you use at home or at school, there is the great book of Nature, wherein each of us, young and old, may read and go on reading all through life, without exhausting even a small part of what it has to teach us.

15. It is this great book—Air, Earth, and Sea—which I would have you look into. Do not be content with merely noticing that such and such events take place. For instance, to return to our walk to the flooded river: do not let a fact such as a storm or a flood pass without trying to find out something about it. Get into the habit of asking Nature questions, as we did in the course of our homeward walk. Never rest until you get at the reasons for what you notice going on around you. In this way even the commonest things will come to wear a new interest in your sight. Wherever you go there will be something for you to notice,—something that will serve to increase the pleasure which the landscape would

otherwise afford. You will thus learn to use your eyes quickly and correctly; and this habit of observation will be of the utmost value to you, no matter what may be the path of life that lies before you.

16. In the following Lessons I wish to suggest the sort of questions you may put about some of the chief parts of the book of Nature, and especially about two of these—the Air and the Earth. Each of us should know something about the air we breathe and the earth we live upon, and about the relations between them. Our walk showed us a little regarding these relations when it enabled us to connect the destruction of fences and farms with the formation of clouds in the sky. Many other relations remain for you to find out. In tracing these you are really busy with science—with that branch of science called Physical Geography, which seeks to describe this earth, with all the movements that are going on upon its surface. And yet you are not engaged in anything very difficult or uninteresting. You are simply watching with attentive eyes the changes that are continually taking place around you, and seeking to find out the meaning of these changes, and how they stand related to each other.

THE SHAPE OF THE EARTH.

17. Before observing what takes place on the surface of the earth, it may be well to form a clear

notion about the shape of the whole earth as a mass, and to fix in the mind some of the great leading features of the connection between the earth and the sun.

18. When one stands in the middle of a broad flat country, or looks out upon the wide sea, it seems as if this world, whereon we live and move, were a great plain, to the edge of which one would come if one went far enough onward. This is the first notion we all have as children. It was also the firm belief of mankind in early times. The sun and moon were once thought to rise and set only for the use of the human race; and the sky, with all its stars, was looked upon as a great crystal dome covering and resting upon the earth.

19. But we can easily prove to ourselves that the eye is deceived about the flatness of the earth, and that what seems quite level is in reality curved. In a wide level country, one cannot see trees and houses farther away than some four or five miles. If we climb to the top of a church-tower, we find many objects come into sight which could not be seen from the ground. And if there happens to be a range of hills in the neighbourhood, we can note from their tops a still larger number of points that before were hidden. The higher one climbs above the ground, therefore, the farther one can see.

20. Again: suppose you were placed by the shore of the open sea, at the bottom of a tall cliff, and on looking seaward were to note the sails of a distant

ship. If you mounted to the top of the cliff, you might see not only the sails, but the whole vessel, and your eye would probably pick out ships still farther away, appearing as mere specks along the line of meeting between sea and sky, and which could not be seen at all from the beach.

21. Suppose, further, that from the top of that cliff you watch these vessels for a time. Some of them, which at first were so far away as to be scarcely visible, would probably seem to grow bigger and clearer. You would begin to make out the tops of the masts and sails; by-and-by the rest of the sails would appear, until at last the hulls too came into sight. These vessels would seem to you to have sailed up over what used to be thought the edge of the world.

FIG. 1.—Disappearance of Ships at Sea owing to the curved surface of the Earth.

22. On the other hand, some of the ships which were near you at first will gradually sail away into the distance. Their hulls will dip down into the sea,

as it were; then the sails will slowly sink, and in the end all trace of the vessels will have vanished.

23. Now, in making these observations, you will have gathered facts which prove that the world we live in cannot be a flat plain. Had it been so, the hulls of the vessels would not have sunk out of sight. Their appearance and disappearance, according as the vessels approached or receded, shows that the earth must have a curved surface, or in other words is a globe.

To use your eyes in this way, and seek out the meaning of that which you see, would neither be a hard nor a dull task; and yet you would really be engaged in what is called observational science. When you watch how the ships at sea appear to you as they come and go, you observe **facts**. When you put the facts together, and reason out their connection and meaning, and find that they prove the earth to be a globe, you make an **induction** or inference from them. Now it is this union of observation and induction which makes **science**.

24. We may observe, then, and prove, that the old and natural-enough notion about the flatness of the earth is quite untrue; and that, flat as the visible portions of the sea and land may appear, they are only parts of a great curve. If we were to set out from home, and to travel on in the same general direction over sea and land without turning back, we should in the end come to our home again. We would travel round the world, and prove it to be

actually a globe. Now, this has often been done. Many voyages have been made round the world, and, instead of coming to its edge, the voyagers or "circumnavigators," as they are called, have always found the land and sea to wear the same curved surface which we can see for ourselves at home.

25. Though it may be easy enough to believe that

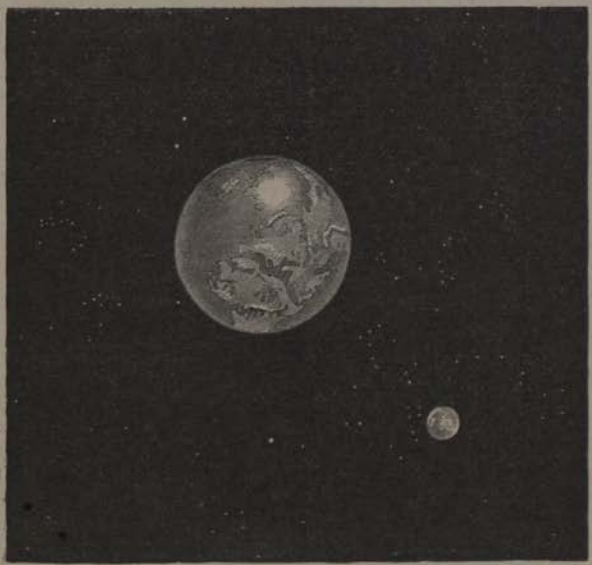

FIG. 2.—The Earth and Moon as they would appear seen from space.

the surface of the earth is part of a curve when one looks out upon the broad sea, yet in a landscape where the ground is very uneven,—such, for example,

as a region of high mountains and deep valleys,—there may perhaps be some difficulty in understanding how such an irregular surface can be spoken of as part of a curve. In reality, however, the earth is so big that even the highest mountains are in comparison merely like little grains on the surface. It is only when the surface is level, as on a great plain or on the sea, that we can usually judge by the eye as to the real form of the earth. But even in the most rugged ground the curve is there, though we may fail to notice it.

26. But the curve, after all, is a very gentle one. You can follow the vessels at sea for many miles before they sink down out of sight. The fact that the curve is so gentle shows that the circle of which it forms part must be of great size. If a sailing vessel could follow a straight course round the earth, it would take many months to complete the voyage. Or if a railway train could go completely round the earth at a rate of thirty miles an hour without stoppage, it would take more than a month to make the circuit.

27. Astronomers have been able to measure the earth, and have found that it is not a perfect sphere, but a spheroid,—that is to say, two opposite sides are depressed or flattened, so that the globe is shaped somewhat like an orange. A line drawn between the two flattened parts or **poles** measures rather more than 7899 miles. This is known as the **polar diameter**. A line from side to side through the

most bulging part or **equator** must be a little more than 7925 miles. This is termed the **equatorial diameter.** Hence the diameter of our earth is about 26½ miles less between the poles than at the equator. You may find it difficult to form any proper notion in your minds of these distances. It is useful to walk for a mile or two between places the distance of which from each other you know, and then to try to realise how many thousand times you must multiply that distance to equal the diameter of our globe.

DAY AND NIGHT.

28. Day by day we have been accustomed all our lives to see the sun travel across the sky. Night after night, when the air has been free from cloud, we have seen the moon or stars sailing slowly overhead. We cannot be more confident of anything than that the sun will appear again to-morrow, and move on from year to year as it has done in the past. A slow, regular, and unceasing motion seems to be going on all round the earth. Have you ever wondered what can be the cause of this motion?

29. When the sun shines it is warm, when clouds obscure the sky the air may grow chilly, and at night we feel a still greater sensation of cold. Again: by day the sky is filled with light, but when the sun sinks in the west darkness begins. Thus, we obviously depend upon the sun for light and heat. But it is evident that what takes place

upon the earth cannot be properly understood until something has been learnt about the relations of the earth to the sun.

30. Our first impression in childhood is like that of mankind in general long ago. They believed the earth to remain as the fixed central point of the universe, round which sun, moon, and stars were ceaselessly revolving. To this day we speak of these heavenly bodies as **rising** and **setting**, as if we still regarded them as performing a journey round the earth.

31. But it has now been known for several hundred years that instead of being the centre of the universe, our earth is in reality only one of a number of heavenly bodies that travel unceasingly round the sun, which is the great central hot mass that warms and lights them. That this must be true will appear if we attentively consider how day and night succeed each other.

32. The alternation of day and night, apparently due to the movements of the sun, is in reality caused by the turning or **rotation** of the earth itself. This may be readily illustrated. A humming-top made to spin rapidly seems to stand for a while motionless upon its point, but it actually is rotating with great rapidity. Imagine a line passing straight up from the point below to the top of the stalk above. Every part of the top is spinning round this central line, which is called the **axis of rotation**. In a similar way the earth is spinning rapidly on its axis.

33. Another illustration may be made with an ordinary school-globe and a lighted candle placed a few feet from it, in a line with the brass circle. The globe can be made to turn round on its axis. Whether it is allowed to remain at rest or is sent spinning round rapidly, the half of it next the candle is lighted, and the other half away from the candle is in shade. When it is at rest, the places marked on one side remain in the light, while those on the opposite side remain in the dark. As it is turned round, each place in succession is brought round to the light, and carried on into the shade again. And while the candle remains unmoved, the rotation of the globe brings alternate light and darkness to each part of its surface.

34. Instead of the little school-globe in this illustration, imagine our earth, and in place of the feeble candle, the great sun, and you will see how the rotation of the earth on its axis must bring alternate light and darkness to every country.

35. No one will imagine that any actual rod passes through the earth, to form the axis round which it turns. The axis is only an imaginary line, and the two opposite points where it reaches the surface, and where the ends of the rod would come out, were the axis an actual visible thing, are called the **North Pole** and the **South Pole**. They are represented by the two little points by which the school-globe is fixed in its place.

36. Round this axis the earth spins once in about

every twenty-four hours. All this time the sun is shining steadily and fixedly in the sky. But only those parts of the earth can catch his light which happen at any moment to be looking towards him. There must always be a bright side and a dark side, just as there is a bright side and a dark side when you place a school-globe opposite to a candle. Were there no motion in the earth, then obviously half of its surface would never see the light at all, while the other half would never be in darkness. But since the earth rotates, every part is alternately illuminated and shaded. When we are catching the sun's light, we have **Day**; when we are on the dark side, we have **Night**.

37. The sun seems to move from east to west. The real movement of the earth is necessarily just the reverse of this, viz. from west to east. In the morning we are carried round into the sunlight, which appears in the east. Gradually the sun seems to climb the sky until we are brought directly opposite to him at noon, and gradually he sinks again in the west, as the earth in its constant rotation bears us round once more into the dark. Even at night, however, we can still trace the movement of the earth by the way in which the stars one by one rise and set, until their lesser lights are quenched in the returning light of another day.

38. While the movement of rotation gives the succession of day and night, another movement of our globe measures out the length of the year.

Not only is the earth rotating on its axis, it is at the same time circling or **revolving** round the sun. This motion is called its **revolution**; and the path which the earth follows in its circuit round the sun is termed its **orbit**. We are ninety-two millions seven hundred thousand miles from the sun, so that to go completely round the sun, the earth has to travel over so wide a circuit or orbit that it takes rather more than three hundred and sixty-five days to perform the journey, even though it is rushing along at an average speed of about nineteen miles in a second.

39. By the motion of rotation, time is divided into days and nights,—by that of revolution, it is marked off into years. So that in this way the earth is our great time-keeper. There are other important results of the earth's movements with which you will afterwards become acquainted.

THE AIR.

I. What the Air is made of.

40. When we begin attentively to consider the world around us, one of the first things to claim notice is the Air. We do not see it, and yet it is present wherever we may go. How profoundly it influences the life of man! How continually it changes its characters, and how much these alterations affect us!—now blowing in a gentle breeze, then sweeping along in a fierce storm, at one time

cold, at another time warm, to-day clear and dry, to-morrow laden with vapour or drenched with rain. What, then, is this Air?

41. Although invisible, it is yet a real, material substance. Swinging your arm rapidly up and down you feel that the air offers a resistance to the hand. The air is something which one can feel, though one cannot see it. We breathe it every moment. We cannot get away from it, for it completely surrounds the earth as an envelope fifty miles or more in depth. Beyond the outer limits of the air, the region between us and the stars is called Space. To the envelope of air enclosing the earth the name of Atmosphere—that is, the region of vapours—has been given.

42. The experiments explained in the Chemistry Primer (Art. 9) prove that air is a mixture of two invisible gases, called **nitrogen** and **oxygen**. Besides these chief ingredients, it contains also small quantities of other substances—some of which are visible, others invisible. When the shutters of a room are closed, so as to let the sunlight stream through only one chink or hole, you see some of the visible particles of the air. Hundreds of little motes or specks of dust cross the beam of light which, reflected from them as they float up and down, makes them visible against the surrounding darkness, though they disappear in full daylight. But it is the invisible parts of the air which are of chief importance; and among them, besides the two chief gases just mentioned, there are two which especially

deserve to be remembered—the **vapour of water** and **carbonic acid gas.**

43. Now what is this vapour of water? In watching what takes place when a kettle boils you notice that from the mouth of the spout a stream of steam comes out into the air. It is in continual motion, rushing out of the spout, but at a short distance away it somehow disappears. All the time that this white cloud is coming and going the water in the kettle is growing less, until at last, if you do not replenish it, the whole will be boiled away, and the kettle be left quite dry. What has become of all the water? It has been changed into steam. It is not destroyed or lost in any way: it has only passed from the condition of visible liquid in the kettle into that of an invisible vapour or gas in the air. But the substance is just as really present in the air, though unseen, as it was when it was poured into the kettle as water.

44. The air always contains more or less vapour of water, which remains invisibly dissolved so long as it continues in the state of vapour. But, as will be explained a little farther on, this dissolved vapour is continually coming back again into visible water. It gives rise to clouds, mist, rain, and snow. If it were taken out of the air, everything would be dried up on the land, and life would be impossible. As you learn more and more of the changes that take place from day to day around you, you will come to see how large a part this vapour of water plays in them.

45. Carbonic acid gas is also one of the invisible gases of the atmosphere, of which it forms about four parts in every ten thousand. This may seem a very minute proportion, but it is enough to supply all the plants that grow upon the land with nearly the whole of their solid substance. Plants have the power of taking the carbon out of the air and building it up into their own framework (Chemistry Primer, Art. 11). When a plant dies and decays, carbonic acid gas is restored to the air again. On the other hand, plants are largely eaten by animals, and help to form the framework of their bodies. Animals in breathing give out carbonic acid gas into the air; and when they die the decay of their bodies returns the same substance again to the soil and the atmosphere. Hence the carbonic acid gas of the air passes into the structure of plants and then of animals, and is once more restored to the air when these living things die and their remains begin to decay. There is, in this way, a continual coming and going of this material between the air and animals and vegetables (Chemistry Primer, Art. 13).

II. The Warming and Cooling of the Air.

46. Though we cannot see the air, we can feel it when it moves. A light breeze, or a strong gale, can be just as little seen by the eye as still air; and yet we readily feel their motion. But even when the air is still, it can make itself sensible in another way, viz. by its **temperature** (Physics Primer, Art.

51). For air, like common visible things, can be warmed and cooled.

47. This warming and cooling of the air is familiar to us in dwelling-houses. If you pass out of a warm room on a winter's day into the open air, you feel cold. Whence does this sensation come? Not from anything you can see, for your feet, though resting on the frozen ground, are protected by leather, and do not yet feel the cold. It is the cold air encircling you on all sides that robs you of your heat; while at the same time you are giving off or **radiating** heat from your skin into the air (Physics Primer, Art. 67). On the other hand, if, after standing a while in the chilly winter air, you return into the room again, you feel warm. Here, again, the feeling does not come from any visible object, but from the invisible air which touches your skin, and is thus robbed of its heat by you.

48. Air, then, may vary greatly in temperature,—that is, it may sometimes be warm and sometimes cold, and yet still remain quite invisible. By means of the thermometer (which is explained in the Physics Primer, Art. 51), we can measure slight changes of temperature, which even the most sensitive skin would fail to detect.

49. Now, how is it that the atmosphere should sometimes be warm and sometimes cold? Where does the heat come from? and how does the air acquire it?

50. Let us return again to the illustration of the

house. In winter, when the air is keen and frosty outside, it is warm and pleasant indoors, because fires are there kept burning. The burning of coal and wood produces heat, and the heat thus given out warms the air. Hence it is by the giving off or **radiation** of the heat from some burning substance that the air of our houses is made warmer than the air outside.

51. Now, it is really by radiation from a heated body that the air outside gets its heat. In summer the air outside is sometimes far hotter than is usual in dwelling-houses in winter. All this warmth comes from the sun, which is an enormous hot mass, continually sending out heat in all directions.

52. But if the sun is always pouring down heat upon the earth, why is the air ever cold? Place a screen between you and a bright fire, and you will immediately feel that some of the heat from the fireplace has been cut off. When the sun is shining expose your hand to its beams for a time, and then hold a book between the hand and the sun. At first your skin is warmed; but the moment you put it in the shade it is cooled again. The book has cut off the heat which was passing directly from the sun to your hand. When the atmosphere is felt to be cold, something has come in the way to keep the sun's heat from directly reaching us.

53. Clouds cut off the direct heat of the sun. We have all often noticed the change of temperature when, after the sun has been shining for a time, a

cloud comes between it and the earth. Immediately a feeling of chilliness is experienced, which passes off as soon as the cloud has sailed on and allowed the sun once more to come out.

54. The air itself absorbs some of the sun's heat, and the greater the thickness of air through which that heat has to make its way, the more heat will be

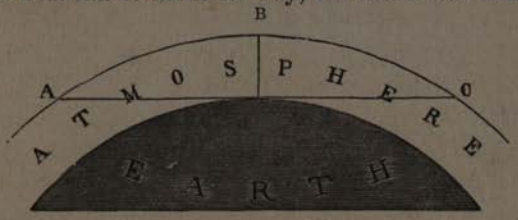

FIG. 3.—Diagram showing the influence of the varying thickness of the Atmosphere in retarding the Sun's heat. A. Line of Sun's rays in the morning. B. Line of the rays at noon. C. Line of the rays at sunset.

absorbed. Besides this, the more the rays of heat are slanted the weaker do they become. At noon, for example, the sun stands high in the sky. Its rays (as at B in Fig. 3) are then nearest to the vertical, and have also the least thickness of air to pass through before they reach us. As it descends in the afternoon, its rays get more and more slanted, and must also make their way through a constantly increasing thickness of air (as at C in the diagram). Hence the middle of the day is much warmer than morning or evening.

55. At night, when the sun no longer shines, its heat does not directly warm the part of the earth in shadow. That part not only receives no heat from

it, but even radiates its heat out into the cold sky (see Art. 59). Hence night is much colder than day.

56. Then, again, during summer the sun at noon shines higher in the sky, or more directly overhead, than in winter. Its heat comes down less obliquely, and has less depth of air to pass through, and hence is more felt than in winter, when the sun in northern parts of the world never rises high even at midday.

57. From all this it is evident that we get our supplies of heat from the sun, and that anything coming between us and the sun serves to interrupt this heat and give us the sensation of cold.

58. Still, if we were dependent for our warmth upon the direct heat of the sun alone, we should be warm only when the sun shines. A cloudy day would be an extremely cold one, and every night as intensely frosty as it ever is in winter. Yet such is not the case. Cloudy days are often quite warm; while the nights are by no means always very cold. There must be some way in which the sun's heat is stored up, so that it can be felt even when he is not shining.

59. Let us again have recourse to our first illustration. The back of a chair placed opposite to a bright fire gets so hot that you can hardly touch it. Remove the chair to a distant part of the room, and it quickly cools. Heat radiated from the fire has been absorbed by the wood, and again given out.

60. In like manner, in summer the ground is warmed; in some parts, indeed, it becomes so hot at times that one can hardly keep the hand upon it.

Soil and stones absorb and radiate heat readily,—that is to say, soon get heated, and soon cool again. When they have been warmed by the sun, the air gets warm by contact with them, and keeps its heat longer than they do; so that even when at night the soil and stones have become ice-cold, the air a little above them is not so chilly. On the other hand, when the surface of the ground is cold, it cools the air next it. As the ground parts easily with its heat, a vast amount of heat is in this way radiated at night from the earth outward into cold starry space.

61. Much more heat, however, would be lost from this cause, did not the abundant invisible aqueous vapour and dust-particles of the atmosphere (Arts. 42, 43) absorb part of it, and act as a kind of screen to retard the radiation. If all the vapour and motes were taken out of the air, the night, owing to the rapidity with which the earth would radiate its heat into space beyond, would be intensely cold. This is the reason why in hot desert climates, where the air is very dry—that is, contains a comparatively small proportion of the vapour of water—the nights are relatively colder than they are in cooler climates where the air is moister, while the days are often intolerably hot. Both the invisible vapour of water dissolved in the air, and the same substance when condensed into visible clouds, serve to keep heat from escaping. Hence cloudy days need not be cold, while cloudy nights are usually not so cold as those which are clear and starry.

62. The atmosphere, then, is heated or cooled according as it lies upon a warm or cold part of the earth's surface; and, by means of its aqueous vapour, it serves to store up and distribute this heat, keeping the earth from such extremes of climate as would otherwise prevail.

III. The Vapour in the Air. Evaporation and Condensation.

63. The presence of water-vapour in the air not only keeps the earth from rapidly losing its heat at night, and screens it from the great heat and glare of the sun during the day, but leads to many other consequences, some of which we must try to understand. First of all, we may inquire how the vapour gets into and out of the air. In this case, as before, we find that great questions in science often admit of being simply and readily illustrated by the most familiar things.

64. In a warm room, where a good fire has been burning all day, and a number of people have been gathered together, the air might be thought to be tolerably dry. But bring a tumbler of ice-cold water into the room, and mark what happens. You will see the outside of the glass immediately covered with a fine film of mist. In a little while minute drops of water will form out of this film, and will go on growing, until, perhaps, some of them unite and trickle down the side of the tumbler.

65. You may have noticed, too, that on very cold

nights, the windows of sitting-rooms or crowded public halls are found streaming with water on the inside.

66. Now, in such cases, where does the moisture come from? Certainly not out of the glass. It is derived from the water-vapour present in the air. This word vapour is often used to describe some kind of visible mist or fog or cloud. But these visible forms of moisture are not properly vapour in the sense in which the term is used in science. The water-vapour of the air is always invisible, even when the air is saturated with it—that is to say, when it cannot retain any more dissolved vapour. Only when the vapour passes back into the state of water is anything actually to be seen.

67. When the invisible vapour dissolved in the air becomes visible, as in mists, clouds, dew, or rain, it is said to be **condensed**, and this process of the conversion of an invisible gas into a visible liquid is called **condensation**.

68. The quantity of vapour which the air can contain varies according to temperature, warm air being able to hold more than cold air. This may be proved in a simple way. In breathing we exhale at each breath a quantity of water-vapour; when the air is warm, this invisible vapour, as soon as it escapes from us, mixes with the outer air, and is kept dissolved there. But if we cool the breath as it leaves our mouths, the vapour is at once condensed into visible moisture. Take a mirror, for example, or any other cold surface, and breathe on it: the vapour from your

lungs at once shows itself in a film of mist upon the glass, because the air in contact with the cold surface is chilled and cannot hold so much vapour, part of which is condensed. During winter a mirror is not required to make the vapour of the breath visible, for the surrounding cold air at once condenses this vapour as it comes from the mouth, and forms the fine cloud or mist which appears with each breath that is exhaled.

69. As the air is cooled, its power of retaining vapour diminishes. When it becomes colder than the temperature at which it is able to keep its supply of vapour dissolved, the excess of vapour is condensed and becomes visible. The temperature at which this takes place is the point of saturation, or **Dew-point** (see Arts. 77, 78).

70. Now let us inquire how it is that the vapour, so universally present, gets into the atmosphere, and where it comes from. Pour a little water into a plate, or, still better, on a black tray, marking precisely the line of the edge of the water, and set it down in the open air. In the course of perhaps an hour or two, unless in very damp weather, the water may be observed to have sensibly diminished. The air has drunk up part of it, and will drink up the whole, if the water is allowed to stand long enough. What takes place from this small quantity of water goes on from every surface of water on the face of the earth, from every brook and river and lake, and from the great sea itself. Water is constantly passing off into

vapour, which is received and retained by the air. This process is called **Evaporation**, and the water which passes off into vapour is said to be **evaporated**.

71. Since warm air can hold more vapour than cold air, evaporation must be more vigorous in sunshine than at night, and during summer than during winter. The sun is the great source of heat that keeps evaporation so active. We are all doubtless familiar with the great difference in the rate at which wet roads dry up. When the sun shines warmly, an hour or two may be enough to drive off the moisture from them, and make them white and hard again. But if the weather is cold and dull, they may remain wet and damp for many days. In the one case, the warm air greedily absorbs vapour from the water on the roads; in the other, the cool air takes it up only in small quantities.

72. Again, it is plain that in damp weather there must be less evaporation than in dry weather. On a dry breezy day, evaporation goes on rapidly, because the air has not nearly all the quantity of vapour it can hold in solution. But on a damp day, when the air contains about as much vapour as it can hold at that particular temperature, evaporation is quite feeble, or ceases altogether. This varying capacity of the air for vapour is the reason why laundresses find such a contrast in the ease with which they can have their clothes dried on different days. Sometimes the air is busy drinking up vapour everywhere, or, as we say, there is great **drought**, and then the

clothes dry quickly. Such is especially the case when the sky is clear and there is a little wind, because every moment a fresh quantity of air comes in contact with the clothes, carries off some of the vapour, and passes on to make way for fresh supplies of thirsty air. At other times, when the air can hardly hold any more vapour, the clothes are found at the end of the day to be almost as wet as when they were hung out in the morning.

73. When water evaporates, the vapour carries away heat with it. Put a drop of water on the back of your hand, and let it evaporate; you feel the part cold, because the vapour as it passes from the drop into the air has robbed your skin of some of its heat. This absorbed heat is given out again into the air when vapour is condensed.

74. The invisible water-vapour in the air, though small in quantity when compared with the amount of nitrogen and oxygen, is yet enormous when the whole mass of the atmosphere is considered. It has been calculated that the amount of vapour that rises every year from the earth's surface into the air would, if condensed, cover with water a country nearly as large as France to the depth of one mile. This vapour is raised in gaseous form from every water-surface over the whole earth by the process of evaporation, and is brought back again into liquid form by the process of condensation.

IV. Dew, Mist, Clouds.

75. After sunset, when the sky is clear, the grass becomes wet with dew. In the morning a white mist or fog may often be noticed hanging over woods, streams, and hills, but gradually melting away as the sun mounts in the sky. At all times of the year clouds may be seen to form and dissolve, and form again, ever changing their size and shape as they move through the air. Now these are all examples of the condensation of vapour. Let us watch how the process takes place.

76. Condensation, as we have seen (Art. 68), arises from a cooling of the air. When vapour is condensed, it does not at once take the form of running water. The cold glass brought into the warm room has first a fine film of mist formed upon it, and then by degrees the clear drops of water come (Art. 64). In reality, mist is made up of exceedingly minute particles of water, and it is the running together of these which makes the larger drops. So in nature on the great scale, when condensation occurs, the vapour first appears as a fine mist. In looking at a mist or cloud as it forms, either in the sky or near the ground, we may be quite certain that air, in which water-vapour is dissolved, is from some cause being cooled down till it cannot hold all its vapour any longer, and must part with some of it.

77. **Dew.**—This name is given to the wetness which appears in the evening or at night upon grass,

leaves, stones, or other surfaces freely exposed to the sky. In the morning, after a dewy night, the little dewdrops sparkle upon the foliage and upon the delicate threads of gossamer. Now this wetness does not come out of the grass, leaves, or stones. It is all derived from the air by condensation, exactly as the film of mist forms upon a cold tumbler in the warm moist air of a room. In fact, that film of mist is really dew, all dew being formed from the same cause.

78. At night, when the sky is clear, the earth radiates heat rapidly; in other words, it gives off into cold space much of the heat which it has received from the sun during the day (Art. 60). Its surface consequently becomes cold, as may be felt by putting the hand upon leaves or stones after nightfall. The layer of air next the cooled ground is chilled below its point of saturation—that is, it is reduced to a temperature at which it can no longer hold so much dissolved vapour. The excess of vapour is deposited as dew upon grass, twigs, stones, and other objects. The temperature at which this condensation begins to take place is called the **Dew-point** (Art. 69).

79. **Mist and Fog.**—Another way in which a cold surface of the earth may produce condensation is shown by what takes place among mountains. When a warm moist wind blows over a chill mountain top, it is cooled, and its vapour becomes visible in the form of a mist or cloud. The cloud may be quite solitary, and may even shape itself to the form of the

ground, as if it were a sort of fleecy cap drawn down over the mountain's head. This is often well marked in the morning. As day advances, the ground, warmed by the sun, no longer cools the air, and hence the mist is gradually re-absorbed into the atmosphere. But by-and-by, at the coming on of night, when the ground is once more cooled by radiation, if there should be vapour enough in the air, the mist may re-form, and the mountain will then put on his cap again.

80. Cold air, as well as cold ground, condenses the vapour of warmer air. Watching what goes on along the course of a river, you will often see examples of this kind of condensation. The ground on either side of the river parts with its heat after sundown sooner than the river itself does, and consequently cools the air above it more than the air above the river is cooled. So when this colder air from either side creeps down to take the place of the warmer damp air lying on and rising from the river, condensation ensues in the form of the mist or river-fog, which so commonly hangs at night and early morning over streams.

81. **Clouds.**—It is not on the ground, however, but up in the air, that the chief condensation of vapour takes place. No feature of everyday occurrence is more familiar than the clouds, which are the result of this condensation. A cloud is merely a mist formed by the cooling of warm moist air which loses its heat from any cause, such as expansion during ascent, or contact with currents of cooler air.

Watching what goes on in the sky, we may often see clouds in the act of forming. At first a little flake of white appears. By degrees this grows larger, and other cloudlets arise and flock together, until at last the sky is quite overcast with heavy clouds, and perhaps, in the end, rain begins to fall. The vapour, thus condensed in the air, has all been obtained by the evaporation of water on the earth's surface. It rises with the warm air, which, expanding and losing heat as it ascends, and also coming in contact with colder layers of the atmosphere, cannot hold all its vapour, and the excess, of which it must get rid, is then condensed into cloud.

82. On a summer morning the sky may be free from cloud; but as the day advances, more vapour is raised from the warmed earth, which, borne upward by the warm ascending air-currents into higher and colder parts of the atmosphere, is there chilled into the white fleecy clouds that form about midday and in the afternoon. Towards evening, when the warm ascending currents die away, and less evaporation takes place, the clouds cease to grow. They then begin to sink in the sky and gradually lessen in size, until at night the heavens may be quite clear again. They have been once more dissolved by descending and coming in contact with warm air nearer to the earth. Again, clouds move across the sky, driven along by upper currents of air. The stronger these currents, the faster do the clouds travel. In this way the sky is sometimes completely

overcast with clouds which have come from a distance. By watching these comings and goings of the clouds, we see how continually the state of the vapour in the atmosphere changes—how at one time it is condensed into clouds, at another time evaporated and invisibly dissolved in the air. The movements of the air are, indeed, in great measure dependent upon the variations and amount of water-vapour (Art. 98).

V. Rain and Snow.

83. The vapour which the sun's heat raises from rivers, lakes, and seas is condensed again into visible form as clouds. But the clouds do not remain always suspended in the sky. They disappear in two different ways. Sometimes, as already noted (Art. 82), they are anew dissolved into invisible vapour. At other times they let their moisture fall through the air to the earth, and thus give rise to rain and snow.

84. **Rain.**—No fact in nature is more familiar than that rain comes from clouds in the sky. When the sky is clear overhead, rain hardly ever falls, but when it becomes overcast, rain often appears. We may watch a dark rain-cloud gather itself together and discharge a heavy shower upon the earth, the long dark streaks of rain being seen actually passing from the cloud above to the ground below. In the illustration of the cold glass brought into the warm room (Art. 64), the film of mist formed upon the

glass is found by degrees to gather into drops, which trickle down the cold surface. Now the mist on the glass and the cloud in the sky are both formed of minute particles or drops of water. It is the running together of these exceedingly small particles which gives rise to the rain-drops. In the one case, the water trickles down the cold glass. In the other case, it gathers into drops of rain that fall through the air. The minute particles of the cloud, as condensation proceeds, grow bigger until they form drops of water too heavy to hang any longer suspended in the air. These then fall to the earth as rain-drops.

85. **Snow.**—But there is another important form in which the moisture of the clouds may descend to the surface of the earth. In countries where the weather is cold enough, there fall to the ground not drops of rain, but flakes of snow.

86. A handful of snow brought indoors soon melts into water, which, on further exposure to the air, evaporates. Snow, water, and water-vapour are thus only different forms of the same substance. The material which we call water can thus exist in three forms,—the gaseous, the liquid, and the solid. Snow is an example of the solid condition.

87. On a frosty night pools of water are covered with a hard transparent crust of what is called **Ice.** You may break this crust into pieces, but if the cold continues, a new crust will soon be formed with bits of the old one firmly cemented in it. And the greater the cold the thicker will the crust be, until perhaps

the whole of the water in the pools may become solid. A piece of this solid substance is found on examination to be cold, brittle, and transparent. Brought into a warm room it soon melts into water, which may easily be driven off, as before, into vapour. Ice is the general name given to water when it is in the solid state, such forms as snow and hail being only forms of ice. Whenever water becomes colder than a certain temperature it passes into ice, or **freezes**, and this temperature is consequently known as the **freezing-point** (Physics Primer, Art. 51).

88. Ice, as we usually see it, might be supposed to be a shapeless thing. But gather a few snowflakes, and, that they may not melt, examine them out of

FIG. 4.—Forms of Snowflakes.

doors. When they lie together in a mass they have a pure opaque whiteness, but in reality they are as transparent as water; and it is only from the way in which they scatter the light from their many glistening points that they appear white. To be assured of this fact, carefully separate one or two of the flakes upon some dark surface (the sleeve of a coat will do well), and you will find that each flake is a more or less perfect star with six rays, formed of little needles or crystals of pure transparent ice. The flakes are so

delicate that in falling through the air they are apt to be damaged by coming against each other. Some of their varieties are shown in Fig. 4.

89. In proportion as we rise above the surface of the earth, the temperature falls. This is observed on any high mountain, and also in balloon-ascents. The upper layers of the atmosphere are much colder than the freezing-point of water. Any vapour, therefore, which is borne aloft by the upstreaming currents of warm air from the earth's surface is frozen in these high regions, and passes into crystals of ice or snow. The fine white cloudlets which may be seen floating at great heights are probably formed of snow. But in countries, such as the northern parts of Europe and North America, where in winter the air even at the surface is sometimes very cold, snow falls to the ground and lies there as a white covering, until returning warmth melts it away.

90. Besides rain and snow, the moisture of the air takes sometimes the form of **Hail**, which consists of little lumps of ice like frozen rain, and of **Sleet**, which is partially-melted snow. But rain and snow are the most important, and we will follow them a little farther, to learn what part they take in the changes that affect the surface of the land. (See Arts. 104, 187.)

VI. The Movements of the Air.

91. A very little attention suffices to show that the air is never at rest. For the most part we can

feel its movements, from the gentlest breeze up to a high gale. And even when it is so still that we are not sensible of any motion in it at all, we have only to watch the leaves on the trees, or the smoke ascending from chimneys, to see that at least slight puffs of air must arise, for the leaves now and then quiver, and the smoke seldom goes up quite straight, but turns as it is borne away to one side or the other. Let us consider how the air is set in motion.

92. The air lying next to a hot surface is heated; the air touching a cold surface is cooled. Hot or warm air is lighter than cold air. Heat expands bodies (Physics Primer, Art. 49), and this expansion of air, or the separation of its particles farther from each other, makes it less dense or heavy than cold air, where the particles lie more closely together. As a consequence of this difference of weight or density, the light warm air rises, and the heavy cold air sinks. This statement may be readily tested by experiment. Take a poker, and heat the end of it in the fire until it is red-hot. Withdraw it, and gently bring some small bits of very light paper, fine down, or some other light substance a few inches above the heated surface. The bits of paper or fibres of down are carried up into the air. This happens because the air heated by the poker immediately rises, and its place is taken by colder air, which, on getting warmed, likewise ascends. Holding the hot end of the poker between our eyes and

the light, we may actually see the tremour of the upstreaming air, by the way in which it distorts the outlines of objects beyond.

93. Fireplaces are constructed on the principle that heated air ascends. The fire is not kindled on the hearth, for, in that case, it would not get a large enough draught of air underneath, and would be apt to go out. It is placed a little above the floor, and a chimney is put over it. As soon as the fire is lighted, the air next it, being warmed, begins to mount, and the air in the room is drawn in from below to take the place of that which rises. All the air that lies above the burning coal becomes warmer and lighter; it therefore flows up the chimney, carrying with it the smoke and gases. Though a bright blazing fire is a pleasant sight in winter, only a part of its heat goes to warm the room. A great deal of the heat goes up the chimney; and, except in so far as it warms the walls, passes away and warms the outer air. But an open fireplace has the advantage of causing a constant draught of air from outside into the room, to supply the place of the warmed air that passes out by the chimney. It thus promotes ventilation. A close stove, on the other hand, in which the indraught of air into the burning coal or wood is made comparatively small, and in which a large warm surface of metal or earthenware thoroughly warms a room, does not help ventilation, which must be otherwise provided for, in order to keep the air from soon becoming close and unhealthy.

94. What happens in a small way in houses takes place on a far grander scale in nature. As already pointed out, the sun is the great source of heat which warms and lightens our globe. While the heat of the sun is passing through the air, it does very little in the way of warming it; but it warms the surface of the earth. In summer, the direct rays of the sun may be hot enough to burn one's face, and yet even a thin sheet of paper, placed between the face and the sun, at once arrests the sensation of burning heat, although the same air is playing about the face all the time.

95. Both land and water are heated by the sun's rays, and the same kind of movement of the air takes place as can be watched by the fireside. The layer of air next the warmed earth becomes itself warmed. As it thereby grows lighter it ascends, and its place is taken by colder air, which flows in from the neighbourhood to take its place. This flowing in of air is **Wind**.

96. It is easy now and then to watch how wind arises. Suppose, for instance, that during the summer we visit the sea-coast. In the morning and early part of a calm clear day a gentle wind will often be noticed, blowing from the sea to the land. As the day advances, this wind increases in force until the afternoon, when it begins to lessen and then to die away. But in the evening, another breeze may be noticed springing up from the opposite quarter, and blowing with a delicious coolness

from the land to the sea. These **land-** and **sea-breezes** are the result of the unequal heating and cooling of sea and land.

97. Let us understand how this takes place. On a hot day, stones, soil, or other parts of the land become warm under the sun's rays; yet if one bathes in the sea at that time, one feels its waters to be pleasantly cool. This shows that the land becomes more quickly hot than the sea. On the other hand, after such a hot day the surface of the land becomes at night much colder than the sea. It parts with its heat sooner than the sea does. By day, the hot land heats the air above it, and makes it lighter, so that it ascends; while the cooler and heavier air lying on the sea flows landward as a cool and refreshing sea-breeze. By night, this state of things is just reversed; for then the air which lies on the chilled land, being colder and heavier than that which covers the warmer sea, flows seaward as a cool land-breeze.

98. It is clear, then, that one main cause of the movements of the air must be differences of temperature. But another highly important cause of these movements is to be found in the constant changes in the quantity of water-vapour present in the air. This vapour being lighter than air, a mixture of vapour and air is lighter than the same quantity of air; and of course the more the amount of vapour increases, the less dense does the mixture become. The weight or **pressure** of the atmosphere is

measured by the familiar instrument called the **Barometer.** The greater the pressure the farther the barometer rises, and the lower the pressure the more it falls. The effect of the ascent of much water-vapour into the air is to lessen the pressure and make the barometer fall. A low barometer, as it is called, generally accompanies wet and stormy weather.

99. Any change in the weight or pressure of the atmosphere, caused by the addition of more water-vapour, must give rise to movements of the air. The lighter mixture of warm air and vapour ascends, and heavier air flows in from all sides to supply its place. The law of atmospheric circulation is that the air always flows from a region of high to one of low pressure.

100. When, from alteration of temperature or from variation in the amount of water-vapour, the weight of the air over one region is rapidly made less than over other surrounding districts, the air from these places flows violently into the central region, and the greater the difference between the pressure of the atmosphere in two neighbouring areas, the more furious will the inrush of air be. To this cause storms and hurricanes are due.

101. There are certain regions of the earth's surface where the pressure of the air is always high, and others where it is always low; consequently there is a continual interchange of air between these regions. The wind blows from the high-pressure

tracts into those of low pressure. The chief region of low pressure encircles the globe as a great belt round the equator, and for some distance on either side. The air is there warm and moist, and evaporation is rapid. Consequently there is a constant upstreaming of warm moist air, which, as it rises farther from the earth's surface, condenses into copious rains. But the ascent of this equatorial hot air requires the instreaming of cooler air from regions of higher pressure lying to the north and south. This constant flowing of air into the equatorial regions forms what are known as the **Trade Winds**. The steadiness of these winds, and the way in which they may be counted upon in navigation, led long ago to their being called by their present name.

102. But whether gentle and constant, or fitful and violent, the cause of wind is always to be sought in differences between the weight or pressure of the atmosphere in adjacent districts, the rule being that wind always blows from where the pressure is high to where it is low.

THE CIRCULATION OF WATER ON THE LAND.

103. In the foregoing pages we have found that from every sheet of water on the face of the globe the air receives vapour; that this vapour is condensed into visible form, appearing as dew, mist, and cloud;

that the vapour of which clouds are formed is resolved into rain, snow, hail, or sleet, and, in one or other of these forms, descends to the earth again. There is thus a circulation of water between the solid earth beneath and the air above. This circulation is as essential to the earth, in making it a fit habitation for living things, as the circulation of blood is in keeping our bodies alive. It mixes and washes the air, clearing away impurities, such as those which rise from the chimneys of a town. It moistens and quickens the soil, which it renders capable of supporting vegetation. It supplies springs, brooks, and rivers. In short, it is the very mainspring of all the life of the globe. So important a part of the machinery of the world deserves our careful consideration. Let us next attend, therefore, to what becomes of rain and snow after they have been discharged from the air upon the surface of the earth.

I. What becomes of Rain.

104. Although water is continually being evaporated from the surface of the earth, and continually restored to it again by condensation, yet, on the whole and in the course of years, there seems to be no sensible gain or loss of water in our seas, lakes, and rivers; so that the two processes of evaporation and condensation balance each other.

105. It is evident, however, that the moisture precipitated at any moment from the air is not at

once evaporated again. When a shower of rain falls, the roads are not dry the moment the shower is over. And when heavy rain continues for many hours together, the whole country round may be flooded, and may remain so for days after the rain has ceased. The ground in the end becomes dry again, and the disappearance of the water from it is due in part to evaporation, but only in part. A great deal of the fallen rain goes out of sight in other ways.

106. As the surface of the sea is about three times greater than that of the land, the quantity of rain that falls upon it is probably the largest part of the whole rainfall of the globe; although, on the other hand, the high and cold parts of the land receive no doubt a far heavier rainfall than any part of the sea. Mingling with the water of the sea, rain helps to make up for the loss which the sea is always suffering by evaporation. For the sea is the great evaporating surface whence most of the vapour of the atmosphere is derived.

107. The total amount of rain that falls upon all the land of the globe must be enormous. It has been estimated, for example, that about 68 cubic miles of water annually descend as rain even upon the surface of the British Isles, which is not one of the wettest parts of the globe. In some parts of India there is so much rain in the year that if it were to remain where it falls it would cover the ground to a depth of 41 feet.

108. But rain does not lie where it falls. It soon disappears, and in a way that deserves close attention. Watch what happens during a shower of rain. If the shower is heavy, little runnels of muddy water course down the streets or roads, and flow out of the ridges of the fields. Follow one of these runnels. It leads into some drain or brook—the brook into some larger stream—the stream into a river; and the river, if you follow it far enough, will bring you to the sea. The rain, therefore, in part at least, flows off the land into the sea. When we consider the great number of brooks and rivers in the world, where this kind of transport of water is going on, we see how vast must be the amount of rain-water carried into the sea.

109. But a very little reflection will convince you that only a part of the rain flows off by brooks and rivers. Since from every water-surface vapour rises into the atmosphere, part of the rain which reaches the ground is, no doubt, at once evaporated, and this evaporation must continue as long as the water remains exposed to the air. Experiments and measurements have been made to ascertain what proportion of the rainfall is lost by evaporation, and it has been inferred that this proportion amounts to from three-fourths to two-thirds; in other words, only about a third or fourth part of the total rainfall is discharged into the sea by rivers.

110. Further observation, however, will lead you

to perceive that there is yet another direction in which the rain goes out of sight. Suppose that after the soil has been baked by a long drought, heavy rain should come, and that you then dig up a spadeful of earth. Do you find the ground dry now? No; because some of the rain has soaked into the earth. And if you could dig deep enough, or would notice what goes on when workmen are making a deep excavation, you would find that the ground underneath the soil is not merely damp, but that it contains plenty of water, and that this water can be collected and brought up to the surface. Clearly, then, a good deal of the rain which falls upon the land must sink underground and gather there. When it disappears in this way, is it finally withdrawn from the general circulation which we have been tracing? or if not, how can it ever get up to the surface again?

111. Consider the matter for a little, and you will be convinced that, whatever becomes of it, the water that descends below the soil cannot be lost to the general circulation. If it were for ever removed from the surface, the quantity of water upon the earth would be constantly and visibly diminishing. The seas would get narrower and shallower; the rivers and lakes would dry up. But no such changes, so far as can be seen, are really taking place. The sea rolls as broadly and deeply as it has done for many generations past; the lakes and rivers remain very much the same.

So that if any of the water that sinks into the earth is never restored to the surface again, it must be so small a part as to make no sensible difference on the amount which is restored. In spite of the rain that disappears into the ground, the circulation of water between the air, the land, and the sea, continues without perceptible diminution.

112. Obviously, therefore, there must be some means whereby the water underground is brought back to the surface. This is done, as you will learn in the next section, by **Springs**, which gush out of the earth and bring up water to feed the **Brooks** and **Rivers**, whereby it is borne into the sea.

113. You can now answer the question, What becomes of the Rain? Part of it sinks into the earth, and afterwards comes out again in springs; part of it flows off at once into brooks and rivers; but of the total rainfall upon the land only about a third or fourth part appears finally to be discharged by rivers into the sea, the rest being lost by evaporation.

114. Here, then, are two distinct courses which the rain takes on reaching the earth—one below ground, and one above. It will be most convenient to follow the underground portion first.

II. How Springs are formed.

115. A little attention to the soils and rocks which form the surface of a country will show that they differ greatly from each other in hardness, and

in texture or grain. Some are quite loose and porous, others are tough and close-grained. They consequently differ much in the quantity of water they allow to pass through them. A bed of sand, for example, is **pervious**—that is, will let water sink through it freely, because the little grains of sand lie loosely together, touching each other only at some points, so as to leave empty spaces between. The water readily finds its way among these empty spaces. In fact, the sand-bed may become like a kind of sponge, quite saturated with the water which has filtered down from the surface. A bed of clay, on the other hand, is **impervious**; it is made up of very small particles fitting closely to each other, and therefore offering resistance to the passage of water. Wherever such a bed occurs, it hinders the free passage of the water, which, unable to sink through it from above on the way down, or from below on the way up to the surface again, is barred back by the clay, and forced to find another line of escape.

116. Sandy soils are dry because they allow the rain at once to sink through them; clay soils are wet because they retain the water, and prevent it from freely descending into the earth.

117. When water from rain or melted snow sinks below the surface into the soil, or into rock, it does not remain at rest there. Where a deep hole is dug in the ground, the water which lies between the particles of the soil or rock begins to

trickle out of the sides of the excavation, and gathers into a pool in the bottom. If the water is baled out, it still keeps oozing from the sides, and the pool is ere long filled again. This shows that underground water will readily flow into any open channel which it can reach.

118. Now the rocks beneath us, besides being in many cases porous in their texture, such as sandstone, are all more or less traversed with cracks, or "joints" as they are called—sometimes mere lines, like those of a cracked window-pane, but sometimes wide and open clefts and tunnels. These numerous channels serve as passages for the underground water. Hence, although a rock may be so hard and close-grained that water would hardly soak through it at all, yet if it be much cracked or jointed, it may allow a large quantity of water to pass through. Limestone, for example, is a very hard rock, through the grains of which water can make but little way; yet it is full of joints, which are often so wide as to give passage to a great deal of water.

119. In hilly districts, where the surface of the ground has not been brought under the plough, many places are marshy and wet, even when the weather has long been dry. The soil everywhere around has perhaps been baked quite hard by the sun; but these places remain still wet, in spite of the heat, because water must there be oozing out of the ground. It is this constant outcome of water

from below which keeps the ground wet and marshy. In other places the water does not merely soak through the ground, but comes gushing out as a **Spring.**

120. Springs are the natural outlets for underground water. But, we may ask, Why should this water have any outlets? When once it has sunk below the surface, what should ever cause it to rise again? To be able to answer this question, let us consider the conditions in which the underground water is placed. All the part of the solid globe which we see, or which can be examined by means of mining and boring, consists of two great series of rocks. In one of these the materials are arranged in parallel layers or strata, as sand, gravel, and mud are laid down in sheets one above another at the bottom of lakes, rivers, and seas at the present time. Rocks of this kind are called Stratified (Fig. 5). In the other series the rocks have no such regular structure, but are traversed by many planes of division or "joints." They are said to be Unstratified. These two kinds of rock give passage to the underground water, each in its own characteristic way.

121. The following diagram (Fig. 5) represents the way in which stratified rocks lie with regard to each other, and in which they may be seen in many a long deep trench or section, such as a valley or river ravine, a railway cutting or quarry. Let us suppose *a* to be a layer of some impervious rock, like clay, and *b* another layer of a porous material, like sand.

The rain which falls on the surface of the ground, and sinks through the upper bed (*b*) will be arrested by the lower one (*a*), and made either to gather there or to find its escape along the surface of that lower bed. If a hollow or valley should have its

FIG. 5.—Section of Strata to show the origin of Surface Springs.

bottom below the level of the line along which the water flows, springs will issue along the sides of the valley, as shown at *s s* in the woodcut. The line of escape may be either, as in this case, the junction between two different kinds of rock, or some of the numerous joints by which stratified as well as unstratified rocks are traversed. Whatever it be, the water cannot help flowing onward and downward, as long as there is any passage by which it can find its way; and the rocks underneath are usually so full of cracks that it has no difficulty in doing so.

122. But a great deal of the underground water must no doubt descend far below the level of the valleys, and even below the level of the sea. And yet, though it should sink to a considerable depth, it comes at last to the surface again. In order to realise clearly how this takes place, let us in imagination follow a particular drop of water, from the

time when it sinks into the earth as rain to the time when, after long journeying up and down in the bowels of the earth, it once more reaches the surface. It soaks through the soil together with other drops, and joins some feeble trickle, or some more ample flow of water, which works its way

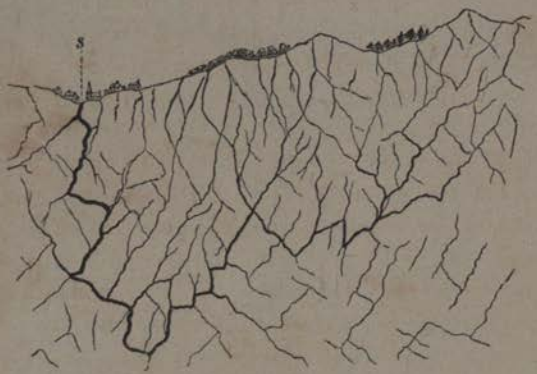

FIG. 6.—Section of part of a district of Unstratified Rocks to show the origin of deep-seated Springs. The numerous joints in the rocks lead the water down into a main channel, by which it re-ascends to the surface as a spring at *s*.

through crevices and tunnels of the rocks. It may thus descend to a depth of several hundred feet through both stratified and unstratified rocks, until it reaches some rock through which it cannot readily make further progress. All this while it has been followed by other drops, coursing after it through its winding passage down to the same barrier at the bottom. The union of all these drops

forms an accumulation of water, which is continually pressed by what is descending from the surface. Unable to work its way downward, the pent-up water must try to find escape in some other direction. By the pressure from above it is driven through other cracks and passages, winding up and down until at last it comes to the surface again at some point lower in level than that from which it started on its underground journey. It breaks out there as a gushing spring (see Physics Primer, Art. 23).

123. Thus every spring which issues out of the ground is a proof of a circulation of water underneath, as well as upon the surface of the land. But besides these natural outlets, other evidence of the same circulation is afforded by artificial openings made in the earth. Holes, called **Wells**, are actually dug to catch this water as it oozes or filters through subterranean rocks. Mines, pits, quarries, and deep excavations of any kind, are usually troubled with it, and need to be kept dry by powerful engines that remove the water. But so abundant often is the underground circulation that the water may gather almost as fast as it is pumped out.

III. The work of Water under ground.

124. No form of water seems purer than the clear crystal spring as it comes bubbling out of the earth. Water, perfectly pure in a chemical sense, should consist only of the two elements Oxygen and

Hydrogen. But in the water of every spring, no matter how clear and sparkling it may be, there is something else. If perfectly pure water were boiled down, the whole of it might be driven off in steam, and nothing would be left behind. But although the most delicate apparatus and the most laborious care have been engaged, it has hitherto been impossible to get water that is absolutely pure. Even rain, which is the purest natural form of water, takes up a little impurity from the air. But this impurity is insignificant compared with what is present in the water of any ordinary spring. When a quantity of spring water is boiled down, a residue of solid matter is left behind. Sparkling transparency is thus no guide to the chemical purity of the water (see Chemistry Primer, Arts. 20, 21).

125. If, now, rain is water nearly in a state of purity, and if after journeying underground it comes out again in springs, always containing more or less of something besides mere water, it must get this addition from the rocks through which it travels. The substances so taken up are not visible to the eye, for they are held in what is called chemical solution (Chemistry Primer, Art. 23). When a few grains of salt or sugar are put upon a plate, and water is poured over them, they are dissolved in the water and disappear. They enter into union with the water. We can no longer see them, but may recognise their presence by the taste which they give to the water that holds them in solution.

126. Rain sinking into the soil dissolves a little of the earthy substances through which it passes. As the water trickles through the subterranean rocks, it also dissolves a portion of their materials. But soil and solid rock are not acted on quite so easily, or in the same way, as salt or sugar. Let us try to understand how they are eaten away by water.

127. We have already learnt that one of the important ingredients in the air is carbonic acid gas, and that this substance is both abstracted from and supplied to the air by plants and animals (Art. 45). In descending through the atmosphere, rain absorbs a little air. As ingredients of the air, some carbonic acid gas, and other gases and vapours, particles of dust, minute organisms, and other substances floating in the air, are caught up by the descending rain, which in this way, as it were, washes the air, and tends to keep it much more wholesome than it would otherwise be. Those who live in a town should make the experiment of catching a little rain in a carefully-cleaned dish, and evaporating some of it to dryness on a clean piece of glass. They will find a thin film left behind which, on being largely magnified, will be seen to be full of little flakes and fragments of town soot and dust, with occasional crystals of salt or some other mineral substances present in the air.

128. But rain not merely picks up impurities from the air,—it gets a large addition when it

reaches the soil. In a handful of earth from a field or a garden you may notice the tiny fibres of decaying roots and leaves. Soil always contains more or less organic matter—that is, some of the substance of dead plants and animals. And with this substance are associated carbonic and some other acids (Arts. 45, 138, 156). If you put some of the soil on a piece of iron and thrust it into the fire, you will burn off the organic matter, remove the carbonic acid, and change the colour of the soil.

129. Armed with the carbonic acid which it gets from the air, and also with the larger quantity of this acid, as well as of various other acids, supplied by the decaying organic matter, which it abstracts from the soil, rain-water is prepared to attack rocks, and to eat into them in a way which pure water could not do (see Chemistry Primer, Experiment 28).

130. Water containing these acids has a remarkable effect on many rocks, even on some of the very hardest. It dissolves more or less of their substance, and removes it. When it falls, for instance, on limestone, it dissolves and carries away some of the rock in solution, though still remaining clear and limpid. In countries where limestone is an abundant rock, this action of water is sometimes singularly shown in the way in which the surface of the ground is worn into hollows. In such districts, too, the springs are apt to be hard—they contain so much mineral matter in solution as to

require more than the ordinary amount of soap for domestic purposes; whereas rain-water and springs which contain little impurity, and require comparatively little soap, are termed **soft** (Chemistry Primer, Art. 26).

131. Many of the substances abstracted by the water of springs are useful in the life of plants and of animals. Lime, salt, and iron, for example, are all brought up in spring-water, and are all of great value. Lime furnishes material for the bones of animals, and iron supplies the colouring matter of their blood. We obtain, indeed, most of what we need of these materials from our solid food; yet spring-water, in so far as it contains them, is healthier for drinking and cooking than rain-water would be.

132. As every spring throughout the world is busy bringing up materials of some kind to the surface, it is plain that the amount of rock thus dissolved and removed must in the end be very great. Channels and tunnels are formed underground especially in limestones, for the water is always eating away a little of the surface over which it flows, thereby widening the cracks and crevices, and converting them by degrees into wider passages. In this way caverns many feet high and many miles long have been formed underneath the surface in different parts of the world. Here and there, too, the roofs of these caverns fall in, and rivers, engulfed in the subterranean

passages, sometimes flow a long way there before they once more make their way to the surface (Fig. 7).

FIG. 7.—Subterranean Channel dissolved out of Limestone-rock by Water.

IV. How the surface of the Earth crumbles away.

133. When a stone building has stood for a few

hundred years, the smoothly-dressed face which its walls received from the mason is usually gone. The stones are worn into holes and furrows, the carvings over window and doorway are so wasted that perhaps one cannot make out what they were meant to represent. This time-eaten character of old masonry is so familiar that we always look for it in an old building, and when it is absent we are inclined to doubt whether the building can really be old.

134. Again, in the burying-ground surrounding a venerable church the tombstones are more and more mouldered the older they are. Sometimes, especially on marble slabs exposed to the open air in towns, the inscriptions dating from more than two or three generations back are so greatly wasted that they no longer tell whose names and virtues they were set up to commemorate.

135. This crumbling away of hard stone with the lapse of time is a familiar fact. But have you ever wondered why the stone should crumble? What makes it decay, and what purpose in nature is served by the process?

136. In the case of buildings and other works of human construction, the nature and rate of decay can be noted and measured, for the stones, rough and worn as they may be now, left the hands of the masons with smoothly-dressed surfaces. But the decay is not confined to human erections. What we see so strikingly in them is only a specimen

of what goes on over the whole face of the world.

137. You should take every opportunity of verifying, by your own personal observation, the statement that the surface of the earth is crumbling away. Examine all the old buildings and exposed pieces of sculpture within your reach. Look at the cliffs and ravines, the crags and water-courses, in your neighbourhood. At the base of each cliff you may find the ground cumbered with blocks and heaps of lesser fragments that have fallen from the rocks above. In countries where the winters are cold, much damage is done to cliffs by frost (Art. 140), and one may sometimes see there the fresh scar whence a new mass has been detached to add to the pile of ruins below. In spite, therefore, of their apparent steadfastness, even the hardest stones are really crumbling down, for wherever exposed to the air they are in every climate liable to decay. Now let us see how this change is ordinarily brought about.

138. First of all, we must return for a moment to the action of carbonic acid and organic acids, which has been already (Arts. 128-130) described. We have found that rain-water, by means of the carbonic and other acids which it abstracts from the air and soil, is enabled to eat away some parts of the rocks beneath. The rain which rests upon or flows over the surface of the ground acts in a similar way. It dissolves out, little by little, such portions

of the rocks as it can remove. In the case of some rocks, such as limestone, the whole, or almost the whole, of the substance of the rock is soluble. In other kinds, the portion dissolved is the cementing material whereby the mass of the rock was bound together; so that when it is taken away, the rock crumbles into mere earth or sand, which is readily washed away by the rain. Hence one of the causes of the mouldering of stone is the action of the acids taken up by rain.

139. In the second place, the oxygen of the portion of air contained in rain-water helps to decompose rocks. When a piece of iron has been exposed for a time to the weather, in such a damp climate as that of Britain, it rusts. In the course of years iron railings, unless frequently covered with a protective coating of paint, are crusted with a dirty yellow or brown powder, which seems to eat into them till they are quite worn through. This yellow powder or rust is a compound substance, formed by the union of iron with the oxygen of the air absorbed in rain-water or in the moisture condensed as dew upon the metallic surface. It continues to be formed as long as any of the unrusted iron remains within reach, since, as each crust of rust is washed off, a new layer of iron is laid open to the attacks of oxygen. What happens to an iron railing or a steel knife happens also, though not so quickly nor so strongly, to many rocks. They, too, rust by absorbing oxygen. A crust of corroded material

forms on their surface, and when it is removed by rain, wind, or frost, a fresh layer of rock is reached by the ever-present and active oxygen.

140. In the third place, the surface of many parts of the world is made to crumble down by means of frost. Those who live in climates where the temperature falls below the freezing-point are familiar with some of the effects of frost. When the cold gets very keen, pipes full of water burst, and jugs filled with water are cracked from top to bottom. The reason of this lies in the fact that water expands in freezing. Ice requires more space than the water would do if it remained fluid. When ice forms within a confined space, it exerts a great pressure on the sides of the vessel or cavity which contains it. If these sides are not strong enough to bear the strain to which they are put, they must yield, and hence they are split open (Physics Primer, Art. 61).

141. While soil is usually so porous that rain readily sinks through it, all rocks are also more or less pervious. Even the hardest and densest of them take in some water. Hence, when winter comes, the ground contains moisture, not in the soil merely, but in the rocks. As frost sets in, this pervading moisture freezes. Now, precisely the same kind of action takes place with each particle of water as in the case of a burst water-pipe or cracked jar. It does not matter whether the water is collected into some hole or crevice, or is diffused

among the grains of the rocks and the soil. When it freezes it expands, and in so doing tries to push asunder the walls between which it is confined.

142. Hence arise some curious and interesting effects of frost upon the ground. After a frosty night the small stones upon a road or footpath may often be seen to have been partly pushed out of their beds. As the ground thaws, the surface of the road is covered with a layer of fine mud. The frost separates the grains of sand and clay by freezing the moisture between them, so that when the frozen moisture melts, the particles of soil no longer adhere to each other, but seem as if they had been pounded down in a mortar. Hence frost is of great service to the farmer in breaking up the soil, and opening it out for the roots and fibres of plants. When a surface of rock has been well soaked with rain, and is then exposed to frost, the grains of the rock undergo the same kind of pressure from the freezing of the water in the pores between them. Not being so loose and open, however, as those of the soil are, they withstand the action of the frost better. Of course, the most porous rocks, or those which hold most water, are most liable to suffer from frost; some of them, such as certain kinds of sandstone, being often subject to rapid decay from this cause. Crust after crust is peeled off from the stone, or its grains are loosened from each other and washed away by rain.

143. Again, water freezes not only between the component grains of rocks, but in the joints which were referred to in Art. 118. How joints help the

FIG. 8.—Waste of a Cliff.

action of frost may be observed on the face of a cliff, or in a quarry, where they may be seen as nearly vertical lines of fracture, dividing rocks into large upright blocks or pillars. They help the

quarryman to break the rock into the blocks he needs to extract, and they are also made use of by nature for a similar purpose, and in the following way. Joints, as we have seen (Arts. 118, 121), serve as passages for water in descending from the surface. Every time the water freezes, it tends to push asunder the two sides of the joint between which it is confined. After many winters, it is at last able to separate them a little; then more water enters, and more force is exerted in freezing, until at last the block of rock traversed by the joint is completely split up. When this takes place along the face of a cliff, one of the loosened parts may fall down to the bottom of the precipice.

144. This kind of waste is represented in the accompanying woodcut (*Fig.* 8), which gives a section of a cliff wherein stratified rocks (Art. 120) are traversed by vertical joints. These have been widened along the front, until large blocks have been wedged off and have fallen to the ground. At the same time the blocks of stone between the joints decay on the surface and may eventually stand out as separate columns or pinnacles. In countries exposed to severe winters, the waste caused by frosts along lines of steep cliff is often enormous.

145. In addition to carbonic acid, oxygen, and frost, there are still other influences at work by which the surface of the earth is made to crumble. For example, when, during the day, rocks are highly

heated by strong sunshine, and during night are rapidly cooled by radiation, the alternate expansion and contraction caused by the extremes of temperature loosen the particles of the stone, causing them to crumble away, or even making successive crusts of the stone fall off. In very dry climates this cause acts powerfully (Art. 61). The wind, too, by driving the loosened parts of the rock away, lays bare the parts underneath, and wears down the surface even of hard rocks, by driving grains of sand against them. The sand wastes of the great deserts of the globe are probably due to the gradual decay of the rocks in a dry climate with a great daily range of temperature, and the subsequent heaping up of the crumbled particles by the wind.

146. We thus learn that, from a variety of causes, solid rocks are liable to continual decay and removal. The hardest stone, as well as the softest, must yield in the end, and moulder down. They do not all, indeed, decay at the same rate. Examining more narrowly the wall of an ancient building, we may see almost every variety in the degree of decay. Some of the stones are hardly worn at all, while others may be almost wholly gone. If this occurs in a building, we may be sure it must take place also in nature, and that some cliffs or crags or portions of them will crumble down faster than others, and will do so in a different way. Each variety of stone has its own characteristic style of "weathering."

147. At first we may be inclined to wonder that there should be a general wasting of the surface of the land, and to ask ourselves how this should be in a world that seems so fair and beautiful. We may even be tempted to consider the decay as a misfortune hardly to be explained. But instead of being in any way calamitous, the mouldering of the surface is in reality necessary to make the earth fit to be the dwelling-place of plants and animals. To it we owe the scooping out of valleys and ravines, and the picturesque outlines of crags and hills. Out of the crumbled stones all soil is made, and on the formation and renewal of the soil we depend for our daily food. How this is brought about will be told in the next Lesson.

V. What becomes of the crumbled parts of Rocks. How Soil is made.

148. Take up a handful of soil from any field or garden, and look at it attentively. It appears to be made of particles of sand and clay or earth, with pieces of crumbling stone, and probably also a few vegetable fibres. Now let us try to learn how these different materials have been brought together.

149. We return again to the general mouldering of the surface of the land described in last Lesson. The words "decay," "waste," and others of similar meaning, are applied to this process. But in reality, although the rocks may crumble away, and thereby grow less in size year by year, there is no actual loss

of material to the surface of the earth. The substance of the rock is not destroyed. It only changes its condition and form, and moves into other places. What, then, becomes of all the material continually being worn from the surface of the land?

150. In a former Lesson (Art. 138) we followed the **chemical** action of rain when it dissolves parts of rocks. By the constant repetition of the process, shower after shower, for years together, the rocks become marvellously wasted and worn. But the rain has also a **mechanical** action.

FIG. 9.—Prints impressed on Clay or Sand by Drops of Rain.

151. Watch what happens when the first pattering drops of a shower begin to fall upon a smooth surface of sand, such as that of a beach. Each drop makes a little dint or impression by pressing aside the grains of sand (Fig. 9). On sloping ground, where the drops can run together and flow downward, they are able to push or carry the particles of sand or clay along. This is called a mechanical action; while the actual solution of the particles, as you would dissolve sugar or salt, is a chemical action. Each drop of rain may act in either or both of these ways.

152. We need not be surprised that rain should do so much in the destruction of rocks. It not only dissolves out some parts of them, leaving a crumbling crust on the surface, but it washes away this crust, and thereby exposes a fresh surface to decay. There is, in this way, a continual pushing along of powdered stone over the earth's surface. Part of this material accumulates in hollows, and on sloping or level ground; part is swept into rivers and lakes; while a considerable proportion in the end is carried away into the sea. It is this decayed material which makes swollen streams muddy (Art. 7) and which forms the sand and gravel along the channel of a river or the margin of the sea.

153. It is this crumbled stone, too, which, mingled with the mouldering remains of plants and animals, forms what we call **soil** or vegetable mould. Soils must obviously differ according to the kind of rock out of which they have been formed. Sandstone, for example, will give rise to a sandy soil; limestone to a limy or calcareous soil; clay-rocks to a clayey soil.

154. But for this crumbling of the rocks into soil, the land would not be covered with verdure as it is, for plants get part of their nourishment out of the soil. Bare sheets of undecaying stone would give no footing for roots. The materials of the stone require to be more or less decomposed and broken up before plants can get their required nutriment out of them. But by the decay of their

surface, bare rocks are eventually covered with fertile soil all over the valleys and plains; and only where, as in steep banks and cliffs, they rise too abruptly to let their crumbled remains gather upon them, do they stand up naked and verdureless.

155. As the crumbling of the surface of the land is always going on, there is a constant formation of soil. Indeed, if this were not the case,—if, after a layer of mould had been formed upon the ground, it were to remain there unmoved and unrenewed,—the plants would by degrees take out of it all the earthy materials fitted for their support. Becoming in the end exhausted, it would no longer support such vegetation, at least, as previously lived upon it. But this state of things is prevented by the continual renewal of the soil, partly owing to the supply of fresh materials from the decay of neighbouring rocks or stones, partly owing to the decay of the sub-soil or decomposing rock below the soil. As the surface soil is removed by rain and wind the decay eats down, as it were, into the still unweathered stone beneath, and thus the soil is renewed from below, as fast perhaps as it is washed away at the surface. Even the loose stones in the mould itself are continually crumbling down and making new earth. And thus, day by day, the soil is slowly renewed, and the balance required for the continued growth of vegetation is preserved.

156. Plants also help to form and renew the mould. They send their roots among the grains

and joints of the stones, and loosen them. Their decaying fibres supply the carbonic and other acids by which these stones are attacked, and furnish also most of the organic matter in the soil. Even common earth-worms are of great service in mixing the soil, burying leaves and twigs so as to hasten their decay into mould, and bringing what lies underneath up to the surface.

157. Reflecting upon this decay and renewal of soil, we perceive that in reality the whole surface of the land may be looked upon as travelling down to the sea. The particles worn from the sides and crests of the high mountains may take hundreds or thousands of years on the journey; they may lie for a long time on the slopes; they may then be swept down and form part of the soil of the valleys; thence they may be in after years borne away and laid down on the bed or bank of a river; but at last after many halts by the way, they reach the sea, and are spread out as mud and sand upon its beaches and over its floor.

158. In order to form some idea of the extent to which the surface of the land is cleared of its loose soil, you should notice what takes place after heavy rain. Each little brook becomes muddy from the quantity of soil washed into it by the rain from the neighbouring slopes. The mud that darkens the water is made of the finer particles of decomposed rocks; the coarser parts are moving along at the bottom of the water. Watching these streamlets

at their work, and remembering that what they are doing now they have been doing for ages past, you will understand how greatly the surface of a country may come to be changed by the action of what at first seems so insignificant a thing as Rain.

VI. Brooks and Rivers: Their Origin.

159. We must now go back to an earlier Lesson (Art. 113), where the way in which rain is disposed of was referred to. We saw that one part of the rain sinks under the ground, and we have traced its progress there until it returns to the surface in springs. We have now to follow, in a similar way, the other portion of the rainfall which flows along the surface in brooks and rivers.

160. A familiar illustration of this subject is furnished by a gently sloping road during a heavy shower of rain. Suppose that, as the rain begins, we take our stand at some part of such a road where there is a well-marked descent. At first each of the large heavy drops of rain makes in the dust, or sand, one of the little dints or rain-prints already described (Art. 151). As the shower becomes heavier these rain-prints are effaced, and the road soon streams with water. Now mark in what manner the water moves.

161. Looking at the road more narrowly, we remark that it is full of little roughnesses—at one place a long rut, at another a projecting stone, with many more inequalities which our eye could not

easily detect when the road was dry, but which the water at once discloses. Every little dimple and projection affects the flow of the water. We see how the raindrops gather together into slender streamlets that course along the hollows, and how the jutting stones and pieces of earth seem to turn these streamlets now to one side and now to another.

162. Towards the top of the slope only feeble runnels of water are to be seen. But farther down they become fewer in number, and at the same time larger in size. They unite as they descend; and the larger and swifter streamlets at the foot of the descent are thus made up of a great many smaller ones from the higher parts of the slope.

163. Now this sloping roadway, with its branching rills of rain, coursing down the slope, and uniting into larger streams as they advance, shows very well the way in which the rain runs off the sloping surface of a country or a continent, and we shall return to the illustration again.

164. Why does the water run down the sloping road? Why does a river flow always in the same direction? It does so for the same reason that a stone falls to the ground when it drops out of your hand: because it is under the sway of that attraction towards the centre of the earth to which the name of **Gravity** (Physics Primer, Art. 4) is given. Every drop of rain falls to the earth because it is drawn downwards by the force of this attraction. When it reaches the ground it is still, as much as

ever, under the same influence; and it flows downwards in the readiest channel it can find. Its fall from the clouds to the earth is direct and rapid; its descent from the mountains to the sea, as part of a stream, is often long and slow; but the cause of the movement is the same in either case. The winding to and fro of streams, the rush of their rapids, the roar of their cataracts, the noiseless flow of their deep sullen currents, are all proofs how paramount is the sway of the law of gravity over the waters of the globe.

165. Drawn down, in this way, by the action of gravity, all that portion of the rain which does not sink into the earth must at once begin to move downwards along the nearest slopes, and continue flowing until it can get no farther. On the surface of the land there are hollows which arrest part of the flowing water, and gather it into **Lakes**, just as there are hollows on the road which serve to collect some of the rain into pools. But in most cases they let the water run out at the lower end as fast as it runs in at the upper, and therefore do not serve as permanent resting places for it. Streams that escape from lakes go on as before, working their way to the sea-shore. So that the course of all streams is a downward one; and the sea is the great reservoir into which the water of the land is continually pouring.

166. If the surface of a country were a mere long smooth ridge, like the roof of a house, the rain would

quickly flow down on either side into the sea. But this is by no means the general character of the surface of the land. Mountains, hills, valleys, gorges, and lakes give a most uneven and varied outline. But besides these greater inequalities which strike the eye at once, even places that seem at first level have some slope or some slight unevennesses; just as on the road we found that there may be many little irregularities of surface which might escape notice until the rain revealed them. Water is thus a most accurate measurer of the levels of a country. It will not flow up a slope nor lie at rest upon it, but always seeks the lowest level it can find.

167. Considering this matter further, we see how the rain, though it should fall equally over the whole surface of a country, cannot flow equally over that surface. The ground being uneven, the rain necessarily runs off into the hollows. It is this unevenness, therefore, which causes the rain to collect into brooks, and these into rivers.

168. The brooks and rivers of a country are thus the natural drains whereby the surplus rainfall, not required by the soil or by springs, and not returned to the atmosphere by evaporation, is led back again into the sea. When we consider the vast amount of rain that falls on the land, and the enormous number of brooks in the higher parts of a country, it seems, at first, hardly possible for all these streams to reach the sea without overflowing the lower grounds. But no such inundation takes place; for

when two streams unite into one, they do not require a channel twice as broad as either of their single water-courses. On the contrary, such an union often gives rise to a stream which is not so broad as either of the two from which it flows. But it becomes swifter and deeper. In this way thousands of streamlets, as they come together in their descent, are made to take up less and less room, until the surplus waters of a whole vast region may be borne into the sea by one single river-channel.

169. Some further illustrations of the drainage of a country may be taken from the roadway in rain. Starting from the foot of the slope, we found the streamlets of rain to become smaller and smaller, until towards the top there were none at all. If, however, we descended the road on the other side of the ridge, we should meet with other streamlets coursing downhill in the opposite direction. At the summit the rain seems to divide, part flowing off to one side, and part to the other.

170. In the same way, were we to ascend some river from the sea, we should watch it becoming narrower, and branching more and more into tributary streams, and these again subdividing into almost endless little brooks. But taking any of these branches and tracing it upward, we should arrive in the end at the first beginnings of a little brook, and going a little farther would reach the summit, on the other side of which all the streams would flow to the opposite quarter. The line which separates

two sets of streams in this way is called the **Water-shed** or **Divide**. In England, for example, one series of rivers flows into the Atlantic Ocean, another into the North Sea. In North America many large rivers carry the drainage of the continent eastward from the Rocky Mountains into the Atlantic, and a number of smaller and shorter streams descend the western slope into the Pacific Ocean. If we trace upon a map a line separating all the upper streams of the one side from those of the other, that line will mark the water-shed of the country or continent.

171. But there is one important point where the illustration of the road in rain quite fails. It is only when rain is falling, or immediately after a heavy shower, that rills are seen upon the road. When the rain ceases, the pools begin to dry up, till the road becomes once more firm and dusty. But brooks and rivers do not disappear though the rain ends. In the heat of summer, when perhaps there has been no rain for many days together, the rivers still roll on, smaller usually than they were in winter, but still with ample flow. What keeps them full? We have already learnt in a former Lesson how this question must be answered:—**rivers are fed by springs as well as by rain.**

172. Though the weather may be rainless, springs continue to give out their supplies of water, and these keep the rivers going. But if great drought comes, many of the springs—particularly the shallow ones—cease to flow, and the rivers fed by them

shrink in size, or, where they are of small dimensions, dry up altogether. This is the case with many of the streams in Britain, which are all, comparatively speaking, very small. The great rivers of the globe, such as the Mississippi, drain such vast territories that any mere local rain or drought makes no sensible difference in their mass of water.

173. In some parts of the world, however, the rivers are larger in summer and autumn than they are in winter and spring. The Rhine, for instance, begins to rise as the heat of summer increases, and to fall as the cold of winter comes on. This happens because the river has its source among snowy mountains. Snow melts rapidly in summer, and the water which streams from it finds its way into brooks and rivers, which are thereby greatly swollen. In winter, on the other hand, the snow remains unmelted; the moisture which falls from the air upon the mountains is chiefly snow; and the cold is such as to freeze the brooks. Hence the supplies of water at the sources of these rivers are, in winter, greatly diminished, and the rivers themselves become proportionately smaller.

174. **Summary.**—To sum up what has been stated in this and the preceding Lessons regarding the circulation of water: From the highest parts of the land down to the sea, water is continually travelling downward. It does not pour over the whole surface, but gathers into the hollows, where it forms streams that wind to and fro, always seeking a lower level,

till at last they lose themselves in the sea. From the sea, as well as from all surfaces of water on the land, vapour is constantly rising into the air, whence it is brought back and condensed upon sea and land as rain or snow, to moisten and fertilise the soil, to supply water for springs and underground circulation, and to feed the streams that flow downward into the sea. This circulation of water goes on without ceasing.

VII. Brooks and Rivers: Their Work.

175. In the first pages of this little book we were engaged in watching the doings of a river. Let us now again return to the same scene, but before the storm which was then described. The river is not yet swollen with the sudden and heavy rain. It flows gently over its pebbly channel, not covering the whole of it perhaps, but leaving banks of gravel and pools of water, between which the clear current, much diminished by drought, winds its way. The river seems to be doing nothing else than lazily carrying the surplus water of the land towards the sea. You may be surprised to be told that it has any work to [illegible], and even now is doing it.

176. But consider whence the water of the river comes. We have found that river-water is largely derived from springs, and that all spring-water contains more or less mineral materials dissolved out of the rocks. Every river, therefore, is carrying not merely water, but large quantities of mineral matter, into the

sea. It has been calculated, for instance, that the Rhine in one year carries into the North Sea lime enough to make three hundred and thirty-two thousand millions of oyster shells. This chemically-dissolved material is not visible to the eye, and in no way affects the colour of the water. At all times of the year, as long as the water flows, this invisible transport of some of the materials of rocks must be going on.

177. But let us now again return to our river in flood, when the water is no longer clear, but dull and dirty. We found this discoloration to arise from mud and sand suspended in the water. For hours the swollen, turbid torrent rolls down its channel, and during that time many tons of gravel, sand, and mud must be swept past. Over and above the mineral matter in chemical solution, therefore, the river is hurrying seaward with vast quantities of other and visible materials. The stones on the bottom of the channel may sometimes even be heard knocking against each other, as they are rolled forwards by the flood. And thus it is clear that one great part of the work of rivers must be to transport the mouldered parts of the land which are carried into them by springs or by rain.

178. But rivers, too, help in the general destruction of the surface of the land. Of this we may readily be assured by looking at the sides or bed of a stream when the water is low. Where the stream flows over hard rock, we find the rock is

smoothed and ground away; and the stones lying in the water-course are all more or less rounded and smoothed. When these stones were originally broken by frosts or otherwise from crags or cliffs, they were sharp-edged, like those that gather at the foot of any crumbling precipice or steep bank of rock. But when they fell, or were washed into the river, they began to be rolled and rubbed, until, as their sharp edges were ground away, they were worn into the smooth rounded forms of ordinary gravel. In this process sand and mud are formed, which are swept down by the current, and take their share, like so much polishing powder, in smoothing and wearing down the rocks over which they travel.

179. Thus, while the stones are ground down, they at the same time grind down the rocks that form the sides and bottom of the river-channel over which they are driven. In some of the eddies of the stream, the stones are kept moving round, until they actually excavate deep round cavities, called **pot-holes**, in the solid rock. When the water is low, as during the droughts of summer, some of these cavities are laid bare, and we may then observe how well they have been polished. Their general appearance is shown in Fig. 10.

180. Now, it is clear that two results must follow from this ceaseless wear and tear of rocks and stones in the channel of a stream. In the first place, a great deal of mud and sand must be produced; and, in the second place, the bed of the river must be

ground down so as to become deeper and wider. The sand and mud are added to the other similar materials washed into the streams by rain from the

FIG. 10.—Pot-holes excavated by a Stream in the rocks of its Bed.

mouldering surface of the land. By the deepening and widening of the water-courses, such picturesque features as gorges and ravines are excavated out of solid rock.

181. Let us next inquire what becomes of all the mud, sand, gravel, and blocks of stone which rivers are continually transporting. For this purpose look again at the channel of a river in summer. It is covered with sheets of gravel in one place, beds of sand in another, while here and there a piece of hard rock sticks up through these different kinds of river-stuff. Watch some portion of the loose materials under water, and you may observe it to be continually shifting. A patch of gravel may remain apparently motionless, but at least the upper grains of sand are always changing as the water covers and moves them. In fact, the loose materials over which the river flows are somewhat like the river itself. We may come back after many years and find the river still there, with its ripples and eddies and gentle murmuring sound. But though the river has been there constantly all the time, its water has been changing every minute, as we can watch it changing still. So, although the channel is always more or less covered with loose materials, these are not always the same. They are perpetually being pushed onward, and others, from higher up the stream, come behind to take their place.

182. It is not in the bottoms of the rivers, then, that the material worn away from the surface of the land can find any lasting rest. And yet the rivers do get rid of a good deal of this material as they roll along. You have, perhaps, noticed that a river is often bordered with a strip of flat plain,

the surface of which is only a few feet above the level of the water. Most of our rivers have such margins, and, indeed, seem each to wind to and fro through a long, level, meadow-like plain. Now this plain is really made up of the loam, sand, or gravel which the river has carried along. During floods each river, swollen and muddy, rises above its banks. and spreads over the low ground on either side. Whenever this takes place, the overflowing water moves more slowly over the flats; and, its current being thus checked, it cannot hold so much mud and

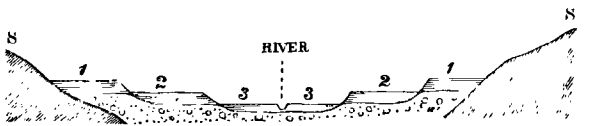

FIG. 11.—Section of the successive Terraces (1, 2, 3) of Sand, Earth, and Gravel formed by a River along a Valley (s—s).

sand, but allows some of these materials to settle down on the bottom. To some extent, too, the water is, as it were, filtered by the vegetation over which it moves upon these inundated plains. In these ways, the overflowed tracts have a coating of soil laid over them by the river, and when the waters retire, this coating adds a little to the height of the plain. The same thing takes place year after year, until by degrees the plain is so far raised that the river, which all this while is also busy deepening its channel, cannot overflow it even at the highest floods. In course of time the current, as it winds

from side to side, cuts away slices of the plain and forms a newer plain at a lower level. And thus a series of terraces is gradually made, rising step by step above the river (Fig. 11).

183. Still, the laying down of its sand and mud by a river to form one or more such river-terraces is, after all, only a temporary disposal of these materials. They are still liable to be carried away, and in truth they are carried off continually, as the river eats away its banks.

184. When the current of a river is checked on entering the sea or a lake, the feebler flow of the water allows the sand and mud to sink to the bottom. By degrees some portions of the bottom come in this way to be filled up to the surface of the river, and wide flat marshy spaces are formed on either side of the main stream. During floods these spaces are overflowed with muddy water, in the same way as in the case of the valley plains just described, and a coating of mud or sand is laid down on them, until they slowly rise above the ordinary level of the river, which winds about among them in endless branching streams. Vegetation springs up on these flat swampy lands; animals, too, find food and shelter there; and thus a new territory is made by the work of the river.

185. These flat river-formed tracts are called **Deltas**, because the one which was best known to the ancients—that of the Nile—had the shape of the Greek letter Δ (*delta*) (Fig. 12). This is the

general form which is taken by accumulations at the mouths of rivers; each flat delta narrows towards the land and broadens towards the sea Some of them are of enormous size; the delta of the Ganges and Brahmaputra, for example, covers an area of between 50,000 and 60,000 miles, or about as large as England and Wales.

FIG. 12.—Delta of the Nile.

186. Each delta, then, is made of materials worn from the surface of the land, and brought down by the river. And yet vast though some of these Deltas are, they do not show all the materials which have been so worn away. A great deal is carried farther out and deposited on the sea-bottom;

for the sea is the great basin into which the spoils of the land are continually borne.

VIII. Snowfields and Glaciers.

187. Having now followed the course taken by the water which falls on the land as rain, we come to that taken by snow (Art. 90).

188. On the lower mountain groups of Central and Southern Europe—such, for instance, as the Harz and Auvergne mountains—snow sometimes lies thickly during winter, but disappears in summer. On the tops of some of the highest mountains in Britain, in shady clefts facing northwards, deep snow-wreaths may be found even in the heat of summer, though only in such cool and sheltered spots does it remain unmelted.

189. But in the Alps, in Norway, in the Himalaya chain, and in other parts of the world, the peaks and higher shoulders of the mountains gleam white all the year with unmelted snow. Hardly anything in the world will impress you so much as the silence and grandeur of these high snowy regions. Seen from the valleys, the mountains look so vast and distant, so white and pure, yet catching up so wonderfully all the colours which glow in the sky at morn or even, that they may seem to you at first rather parts of the heaven above than of the solid earth on which you live. But it is when you climb up fairly into their midst that their wonderful stateliness comes full before

you. Peaks and pinnacles of the most dazzling whiteness glisten against the dark blue of the sky, streaked here and there with lines of purple shadow, or with knobs of the dark rock projecting through the white mantle which throws far and wide its heavy folds over ridge and slope, and sends long tongues of blue ice down to the meadows and vineyards of the valleys. There is a deep silence over this high frozen country. Now and then, a gust of wind brings up from the far distance the sound of some remote waterfall, or the dash of a mountain torrent. At times, too, there comes a harsh roar as of thunder, when some mass of ice or snow, loosened from the rest, shoots down the precipices. But these noises only make the silence the deeper when they have passed away.

190. Let us now inquire into the origin of this lonely and lifeless ice-world. Why should snow everlastingly wrap round the shoulders and summits of the mountains? Of what use is snow on the low ground as well as among the heights?

191. The higher parts of the atmosphere, as already noticed (Art. 89), are extremely cold. In the far north and the far south, around those two opposite parts of the earth's surface called the Poles, the climate is likewise so intensely cold as to give rise to dreary expanses of ice and snow, where sea and land are frozen, and where the heat of summer is able only partially to thaw the accumulated snow of the rest of the year. Between

these two polar tracts of cold, wherever mountains are lofty enough to rise into the high parts of the atmosphere, where the temperature is usually below the freezing-point, the vapour condensed from the air falls upon them, not as rain, but as snow. Their heads and upper heights are thus covered with perpetual snow. In such high mountainous regions, the heat of the summer always melts the snow from the lower hills, though it leaves the higher part still covered. There is a not very definite limit below which the snow disappears in summer, but above which it never wholly departs from year to year. This limit is called the **snow-line**, or the **limit of perpetual snow**. Its height varies in different parts of the world. It is highest in the warmer regions on either side of the equator, where it reaches to 15,000 feet or more above the sea. In the cold polar tracts, on the other hand, it approaches the sea-level. In other words, while in the polar tracts the climate is so cold that perpetual snow is found even close to the sea-level, the equatorial regions are so warm that we must climb to a height of some three miles to reach the cold layers of the air, wherein snow can remain all the year.

192. Those who live in a country where the winter temperature falls to the freezing-point of water have opportunities of seeing a snowstorm. What a contrast it presents to a rainstorm! At first a few flakes begin to show themselves drifting

through the air, and falling so silently that if we did not see them, we should not know that precipitation of any kind was going on in the air. By degrees the flakes grow more in number and larger in size, until the ground begins to whiten. As hours go on, the whole country becomes buried under a white pall, perhaps six inches or more in thickness. And yet, except the whistling of the bitter wind, we may hear no sound from the outer air. Had the fall been of rain instead of snow, how monotonous would have been the noise of the patter of the drops, and the drip and trickle of running water everywhere! In that case too the roads and fields would still have been visible, for each drop of rain, instead of remaining where it fell, would either have sunk into the soil or have flowed off into the nearest brook. But each snowflake, on the contrary, lies where it falls, unless it happens to be caught up and driven on by the wind to some other spot where it can finally rest. Rain disappears from the ground as soon as it can; snow stays still as long as it can.

193. This marked difference of behaviour must obviously lead to still further differences in the work done by these two forms of water. We have followed the progress of the rain; now let us try to find out what becomes of the snow.

194. In a country where there is no perpetual snow this question is easy enough to answer. Each fall of snow in winter time remains on the ground

as long as the air is not warm enough to melt it. Evaporation, indeed, goes on from a surface of snow and ice, as well as from water; so that a layer of snow would in the end disappear by being absorbed into the air as vapour, even though none of it had previously been melted into running water. But it is by what we call a **thaw** that snow in temperate climates is chiefly dissipated—that is, by a rise in temperature, and a consequent melting of the snow. When the snow melts, the water, thereby let loose, sinks into the soil and flows off into brooks, in the same way as rain. Its after-course needs not to be followed, for it is the same as that of rain. We may bear in mind, however, that if a heavy fall of snow should be quickly thawed, a large quantity of water will be let loose over the country, and the brooks and rivers will rise rapidly in flood. Great destruction may thus be caused by the sudden rise of rivers and the overflowing of their banks (Art. 173).

195. In regions of perpetual snow, where the heat of summer cannot melt all the snow that falls there in the year, what other way of escape is open to the frozen moisture? That it must have some means of taking itself off the mountains is clear enough; for if it had not, and if it were to accumulate there from year to year and from century to century, the mountains would grow into vast masses of snow, reaching far into the sky, and spreading out on all sides, so as to bury by degrees the low

lands around. But nothing of this kind takes place. These solemn snowy heights wear the same unchanged look from generation to generation. There is no burying of their well-known features under a constantly increasing depth of snow.

196. As a portion of the rainfall is evaporated again from the moist surface of the land, so the snow too loses a little by evaporation. Even in a frost, when the snow does not melt, we may watch it slowly diminish day by day. But as the surplus rainfall flows off by means of rivers, so among the higher mountains and in the Arctic and Antarctic regions the surplus snowfall above the snow-line flows off by means of what are called **Glaciers.**

197. When a considerable depth of snow has accumulated, the pressure of the overlying mass upon the lower layers squeezes them into a firm condition. The surface of the ground on which the snow gathers is usually sloped in some direction, seldom quite flat. Among the mountains, indeed, the slopes are often highly inclined or precipitous. As snow gathers deeply on these heights, the force of gravity eventually overcomes the tendency of the pressed snow to remain where it is, and the snow then begins to creep down the slope. From one slope it passes on downwards to the next, joined continually by other sliding masses from neighbouring slopes, until they all unite into one long tongue which creeps slowly down the main valley to a point where it melts. This tongue from the snow-

fields is a Glacier. It really drains these snowfields of their excess of snow as much as a river drains a district of its excess of water.

198. But the glacier which comes out of the snowfields is itself made not of snow, but of ice. The snow, as it slides downward, is pressed together into ice. Each snowflake is made of little crystals of ice (Art. 88). A mass of snow is thus only a mass of minute crystals of ice with air between. Hence, when the snow is pressed together, the air is squeezed out, and the previously separated crystals of ice freeze together into a solid mass. Most schoolboys in temperate climates know what snowballs are, and that they can be made very hard by squeezing them firmly between the hands. The more tightly the snow is pressed the harder it gets. In making a hard snowball, therefore, you are treating the snow somewhat in the same way as nature treats it in making a glacier out of the eternal snows. You are pressing out the air, and allowing the little particles of ice to freeze to each other and to form a compact piece of ice. But you cannot squeeze nearly all the air out; consequently the ball, even after all your efforts, is still white. Among the snowfields, however, the pressure is immensely greater and more prolonged than yours; the air is more and more pressed out, until at last the snow becomes clear transparent ice.

199. A glacier, then, is a river, not of water, but of ice, coming down from the snowfields. It descends

sometimes a long way below the snow-line, creeping down very slowly along the valley which it covers from side to side. Its surface all the time is melting during the day in summer, and streams of clear water gush along the ice, but these are frozen and silent

FIG. 13.—View of a Glacier, with its Moraines, Perched Blocks, ice-worn Bosses of Rock, and escaping River.

at night. At last it reaches some point in the valley beyond which it cannot go, for the warmth of the air there melts the ice as fast as it advances. So the glacier ends, and from its melting front streams of muddy water unite into a foaming river, which bears the drainage of the snowfields far down into the plains, and thence to the sea.

200. In the accompanying woodcut (Fig. 13) some of the chief characters of a glacier are shown. In the distance rise the snowy heights, among which the snowfields lie. From either side the snow is drained off into the main valley, where it forms the glacier, which winds with all the windings of the valley till it ends abruptly, and the river gushes out from the melting end of the ice.

201. We may be sure that in this constant movement from the high snowfields down into the valleys, a glacier must be doing work of some kind. A river, as we have seen (Arts. 175-186), wears down the sides and bottom of its channel, and thus digs out a bed for itself in even the hardest rock, as well as in the softest soil. It sweeps down, too, a vast quantity of mud, sand, and stones from the land to the sea. A glacier performs operations of a similar nature, but in a very different way.

202. When stones fall into a river they sink to the bottom, and are pushed along there by the current. When mud enters a river it remains suspended in the water, and is thus carried along. But the ice of a glacier, though it behaves, on the great scale, like what is called a viscous or half-fluid body, moulding itself to the form of the valley down which it moves, is nevertheless a hard brittle substance. Stones and mud which fall upon it from the cliffs and slopes above do not fall into it, as they would do into water, but remain on its surface, and are borne onward with the whole mass of the moving

glacier. The ice is often rent by huge cracks that by degrees open into yawning clefts or **crevasses**. Into these deep gashes in the gleaming ice a good deal of the earth and stones, let loose by frost or otherwise from the sides of the valley, is apt to fall. In this way, loose materials reach the bottom of the glacier and the solid floor of the valley down which it is moving; while at the same time similar rubbish

FIG. 14.—Loose Stone polished and scratched under Glacier-ice.

tumbles between the edge of the ice and the sides of the valley.

203. Stones and grains of sand, jammed between the ice and the rock over which it is moving, are made to scour and scratch this rock. They form a kind of rough polishing powder, wherewith the glacier is continually grinding down the bottom and sides of its channel. Were one to creep in below the ice, or catch a sight of some part of the side from which the ice had retired a little, one would find the surface of rock rubbed smooth, and covered with long scratches made by the sharp points of the stones

and sand. Some of the rounded ice-worn bosses of rock are shown in the foreground of the diagram (Fig. 13), and one of the scratched stones in Fig. 14.

204. If, then, a glacier is continually grinding and polishing the rocks over which it moves, there is an evident reason why the river that escapes from

FIG. 15.—Erratic Block, brought from the Alps by an ancient Glacier, and dropped upon the Jura Mountains.

the end of the ice should always be muddy. The bottom of the glacier is stuck over with stones, gravel, and sand, which are scraping and wearing down the rock underneath. A great deal of fine mud is thus produced, which, carried along by water flowing under the glacier, emerges at the far end in the discoloured torrents that rush from under the ice.

205. A glacier is not only busy grinding out a

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bed for itself through the mountains—it bears on its back, down the valley, enormous quantities of fallen rock, earth, and stones, which have tumbled from the cliffs on either side. These materials are called **moraines** (Fig. 13). Blocks of rock as big as a house may be thus carried for many miles, and dropped where the ice melts. The accompanying figure (Fig. 15) represents one of these huge masses of stone—the *Pierre à Bot*, which has been transported from the Central Alps and dropped on the Jura Hills about 800 feet above the level of the Lake of Neufchâtel. It measures 50 feet in length, 40 feet in height, and 20 feet in width, and must weight more than 3000 tons. Thousands of tons of loose stones and earth are every year moved on the ice from the far snowy mountains down into the valleys to which the glaciers reach.

206. The largest glaciers in the world are those of the polar regions. North Greenland, in truth, lies buried under one great glacier, which pushes long tongues of ice down the valleys and away out to sea. When a glacier advances into the sea, portions of it break off and float away as **icebergs** (Fig. 16). So enormous are the glaciers in these cold tracts that the icebergs derived from them often rise several hundred feet above the waves which beat against their sides. And yet, as the ice, being frozen fresh water, is lighter than the salt water on which it floats, nearly nine times more of the ice lies under water than the portion,

large as it is, which appears above. A piece of ice, for example, put in a tumbler of water shows only its top above the level of the water. Sunk deep in the sea, the icebergs float to and fro until they melt in mid-ocean, or until, driven into shallow water, they are stranded, sometimes many

FIG. 16.—Iceberg at Sea.

hundreds of miles away from the glaciers that supplied them.

207. It has been found out that glaciers once abounded all over the northern part of the north hemisphere, for the rocks in that region have been ground down and scratched, precisely like those by the side of modern glaciers; while big blocks of rock and piles of loose stones, which the ice had

carried upon its surface, are strewn far and wide over the plains. Across the greater part of the British Islands, the whole of Northern Europe, Canada, and the north-eastern States of America, these and many other traces of ancient ice-sheets are to be found. So that, in learning about glaciers, we are not merely concerned with what takes place in other and distant lands, but are gaining knowledge that may be turned to good use in enabling us to understand the remote history of our own country.

208. But even in those regions where snow does not lie permanently on the ground, it performs much work in other ways. For example, it covers up vegetation, soils, and rocks, and shields them from the effects of severe frost. By its rapid thaw it allows a large body of water to flow off quickly into the rivers, which are thus made to rise suddenly and produce disastrous floods (Art. 173). When it collects on the steep slopes of valleys it sometimes slides down in great sheets called **Avalanches**, which, gathering force as they descend, sweep earth, stones, and trees before them, and carry ruin into the meadows below.

THE SEA.

I. Grouping of Sea and Land. General Features of the Sea.

209. Since we live on land, and are familiar

with the various shapes which the surface of the land assumes,—plains, valleys, hills, mountains, and so on,—we are apt to think that the land is the main part of the globe. Many who live inland have never seen any larger sheet of water than a river or a lake, or perhaps a large reservoir. An inhabitant of Great Britain, however, cannot travel far in any direction in his native country without coming to the edge of the land, and finding a vast expanse of water before him. He might take ship and sail on that water completely round Britain, and would prove in so doing that it is an **island.**

210. Suppose that instead of sailing round Britain, the ship were to be steered straight westward. One would have to travel over the water for more than two thousand miles before reaching any land again. Or, taking a more southerly course, one might sail on without seeing any land for months together, until the ice-cliffs that border the land round the South Pole came in sight. Voyages such as these would deeply impress upon the mind what an enormous extent of the surface of the earth is occupied by water.

211. It has been ascertained that in reality the water covers about three times more of the earth's surface than the land does. This has been discovered by men who have sailed round the world, and have crossed it in many directions.

212. When a school-globe is turned slowly round on its axis, we not only see at a glance how much

larger the surface of water is than the surface of land, but may notice several other interesting features in the distribution of land and water.

213. In the first place, the water is all connected together into one great mass, called the **sea**. One might sail from any part of the sea to any other part, without having to cross land. The land, on the other hand, is much broken up by the way the sea runs into it; and some parts are cut off from the main mass of land, so as to form islands in the sea. One cannot pass from every part of the land to every other part without crossing sea.

214. In the second place, much more land lies on the north than on the south side of the equator. Turning the globe so as to look straight down on the site of London, you will find that most of the land comes into sight; whereas from the opposite side you see most of the sea. London thus stands about the centre of the land-hemisphere, midway among the countries of the earth. And no doubt this central position has not been without its influence in fostering the progress of British commerce. New Zealand lies about the centre of the water-hemisphere.

215. In the third place, by the way in which the masses of land are placed, parts of the sea are to some extent separated from each other. These masses of land are called **continents**, and the wide sheets of sea between are termed **oceans**. The surface of the solid part of our globe is uneven, some portions rising into broad swellings or ridges,

others sinking into wide hollows or basins. Now, into these hollows the sea has been gathered, and only those upstanding parts which rise above the level of the sea form the land.

216. In the foregoing parts of this little book mention has often been made of the sea. We have learnt that much of the moisture of the air rises from the sea; that the rivers of the land are continually flowing into the same reservoir of water, which is likewise the great basin wherein the soil worn from the surface of the land is laid down. We must now look a little more closely at several of the more important features of the sea.

217. But, first of all, it may be well to try to realise the general aspect of the sea. Suppose that, standing somewhere by the sea-coast, we see the vast expanse of water for the first time. Behind us lies the dry land, with its fields and houses and roads; but in front, far as the eye can reach, nothing except water can be seen, till, along the distant level line, the sky seems to rest upon the sea. That line where sea and sky meet is called the **horizon.** What a sense of boundless space that wide expanse of sea and sky gives us! As we stand watching it we are soon struck by the restlessness of the sea. Even on the calmest summer day, a slight ripple or a gentle heaving motion may be seen; at other times little wavelets curl towards the land, and break in long lines upon the beach; but now and then, when storms arise, the water is worked up

into huge billows which, crested with spray, come in, tossing and foaming, to burst upon the shores.

218. But if the sight of the sea from the land is so impressive, far more is that of the boundless expanse of mid-ocean. Sailing out of sight of land we see nothing but a wide circle of sea and an over-arching sky. The nearest dry land may be thousands of miles away. The water below the vessel may be two or three miles deep. Day after day and week after week we may sail on, with apparently the same circle of ocean all round and the same vault of sky overhead. Few or no traces of life may be visible either in the air or water. We long for the sight of another vessel, and welcome any stray bird or insect, as a kind of messenger from the land which we so weary to see again.

219. Unlike the common water of our rivers and lakes, the water of the sea is salt. A drop of clear spring-water, if allowed to evaporate from a piece of glass, leaves no sensible trace behind. The water of springs, however (Arts. 130-132), always contains some mineral substances dissolved in it, and these, not rising in vapour, are left behind when the water evaporates. But the quantity of them in a single drop of water is so minute that, when the drop dries up, it leaves no perceptible speck or film. Take, however, a drop of sea-water, and allow it to evaporate. You find a little white point or film left behind, and on placing that film under a microscope you see it to consist of delicate

cubical crystals of common or sea-salt, together with other slender crystals, most of which are gypsum. Breathe on the film, and it rapidly becomes again a drop of water; the salts have united with the condensed moisture and are once more dissolved. A similar experiment is made when one bathes in the sea and allows the salt water to dry on the body. A crust of salt is soon felt to have been left behind upon the skin.

II. Why the Sea is Salt.

220. Where did the salt in sea-water come from? There is reason to believe that, at a very early stage of its history, the earth existed as a mass of intensely hot vapour, such as the sun is now, and that, as it gradually cooled, the various materials successively condensed out of the vapour, so as to build up the solid planet, with its envelopes of air and water. The atmosphere may thus be regarded as the still gaseous residue of the original, far vaster atmosphere, out of which the condensation of the planet took place. The ocean also may be looked upon as the result of later condensations, when the temperature of the earth's surface had sufficiently fallen to allow water to remain there. As it condensed and fell to earth, the water would carry down with it some of the vapours still present in the surrounding warm atmosphere. Among these vapours were probably salts and other substances still dissolved in sea-water.

221. But the sea continually receives salt from the land. Both underground and on the surface of the land, water is always dissolving out of the rocks various mineral substances, of which common salt is one (Arts. 130, 138). Hence, as the water of springs and of rivers contains salt, a vast quantity of this substance must every year be carried into the ocean.

222. Though the sea gives off again by evaporation as much water as it receives from rain and from the rivers of the land (Art. 104), the salt carried into it remains behind. When we evaporate salt water, though the water disappears, the salt it contains is left behind (Art. 219). So is it on a great scale with the sea. While streams are every day carrying fresh supplies of salt into the sea, millions of tons of water are every day also passing from the ocean into vapour in the atmosphere. The water is fresh as it rises into vapour, but is slightly saline as it flows back from the land into the sea. The waters of the sea must, consequently, be getting salter by degrees, though the process, no doubt, is an extremely slow one.

223. Although ever since rivers first flowed into it the sea has been gradually growing in saltness, it is even now by no means as salt as the water of some inland seas which have no outlet to the main ocean. In the Atlantic Ocean, for example, the total quantity of the different salts amounts only to about three and a half parts in every hundred parts of water. But in the Dead Sea, which is

extremely salt, the proportion is as much as twenty-four parts in the hundred of water.

III. The Motions of the Sea.

224. Watching by the shore of the open sea, we perceive that no matter what may be the state of the weather, the surface of the water is never perfectly still. Moreover we may observe that the actual edge of the sea does not remain at exactly the same limit. At one hour of the day it reaches to the upper part of the sloping beach; some six hours afterwards it has retired to the lower part. It falls and rises, day after day, and year after year, with so much regularity that its motion can be predicted long beforehand. To this **ebb** and **flow** of the sea the name of **tides** has been given.

225. An empty bottle, corked up and thrown into the sea, will float; but will not remain long where it first fell. It will begin to move away, and may travel for a long distance until thrown upon some shore again. Bottles cast upon mid-ocean have been known to be carried in this way for many hundreds of miles. This **surface-drift** of the sea-water corresponds generally with the direction in which the prevalent winds blow.

226. But it is not merely the surface-water which moves. Icebergs, for example (Art. 206), are sometimes seen sailing on, even right in the face of a strong wind. This shows them to be moving, not with the wind, which can affect merely the small

part of them that projects out of the water, but with a strong under-current in the sea, in which the greater part of their bulk is immersed. In short, the sea is found to be traversed by many **currents**, like great rivers, some flowing from cold to warm regions, and others from warm to cold. These deep currents and surface-drifts play an important part in the distribution of the different climates that are met with all over the globe. When the water flows from a region where it is heated by the sun it carries warmth to distant regions which would otherwise be cold. Thus it is to the warm water which drifts across the Atlantic that the north-west of Europe owes its mild climate. On the other hand, a current coming from a cold sea chills the air of the countries which it reaches, as Labrador is chilled by the body of cold water that comes out of Davis Strait.

227. Here, then, are four facts about the sea:—1st, it has a restless surface, disturbed by ripples and waves; 2nd, it is constantly heaving with the ebb and flow of the tides; 3rd, its surface-waters drift with the wind; and 4th, it possesses deep and wide currents.

228. For the present, it will be enough to attend to the first of these facts—**the waves of the sea.** Here again we may illustrate by familiar objects what goes on upon so vast a scale in nature. Take a basin or a long trough of water, and blow upon the water at one edge. Its surface is at once thrown

into ripples, which, as you will observe, start from the place where your breath first hits the water, and roll onward until they break in little wavelets upon the opposite margin of the basin.

229. Ordinary waves are disturbances of the smoothness of the sea, due to disturbances of the air. Wind acts upon the water of the sea as your breath does on that of the basin. Striking the surface, it throws the water into ripples or undulations, and in continuing to blow along the surface it gives these additional force, until, driven onwards by a furious gale, they grow into huge billows.

230. When waves roll in on the land, they break one after another upon the shore, as your ripples break upon the side of the basin. And they continue to roll in after the wind has fallen, in the same way that ripples will still undulate in the basin for a little after you have ceased to blow. The surface of the sea, like that of water generally, is very sensitive. If thrown into pulsations, it does not become motionless the moment the cause of disturbance has passed away, but continues moving, in a gradually lessening degree, until it comes to rest. Moreover, the undulations may travel far away from the place where the storm blew that caused them. They roll ashore and break there in waves. This heaving of the sea after a storm is known as Ground-swell.

231. The restlessness of the surface of the sea becomes in this way a reflection of the restlessness

of the air. It is the constant moving to and fro of currents of air, either gentle or violent, which dimples the sea with ripples or roughens it with waves. When the air for a time is calm above, the sea sleeps peacefully below; when the sky darkens, and a tempest bursts forth, the sea is lashed into waves, which roll in and break with enormous force upon the land.

232. Every one who has ever lived upon a coast-line must have heard, or may even have seen, something of the destruction worked by the waves of the sea. Every year piers and sea-walls are broken down, pieces of the coast are washed away, and the shores are strewn with the wreck of ships. So that, besides all the waste which the surface of the land undergoes from rain, frost, and streams, there is another form of destruction going on along the sea-margin.

233. On rocky shores, the different stages in the eating away of the land by the sea can sometimes be strikingly seen. Above the beach, perhaps, rises a cliff, sorely battered about its base by the ceaseless grinding of the waves. Here and there, a cavern has been drilled in the solid wall, or a tunnel has been driven through some projecting headland. Not far off we may note a tall buttress of rock, once a part of the main cliff, but now separated from it by the falling in and removal of the connecting archway. And then, farther from the cliff, isolated, half-tide rocks rise to show where still older detached

buttresses stood; while away out in the sea the dash of breakers marks the site of some sunken reef,—the relics of a still more ancient coast-line. On such a shore the whole process whereby the sea eats into the land seems to be laid open to our eyes.

FIG. 17.—Coast-line worn by the Sea.

234. On some parts of the coast-line of the east of England, where the rock is easily worn away, the sea advances on the land at the rate of two or three feet every year. Towns and villages which existed a few centuries ago have one by one disappeared, and their sites are now a long way out under the restless waters of the North Sea. On the west side of Britain, however, along the coast of Ireland and

Scotland, the rocks being usually hard and resisting, the rate of waste has been comparatively small.

235. Those who have the good fortune to live at or to visit a rocky coast-line should endeavour to ascertain what means the sea takes to waste the land. Let them take their stand on some sandy or gravelly part of the beach, over which the waves are breaking, and keep their eye on the water when it runs back after a wave has burst. The pebbles of gravel and grains of sand may be seen hurrying down the slope with the water. If the gravel happens to be coarse, it makes a harsh grinding roar as its stones rub against each other—a noise which, in storms, is sometimes loud enough to be heard miles away. As the next wave comes curling along, it will be observed that the sand and gravel, after slackening their downward pace, are caught up by the bottom of the advancing wave and dragged up the beach again, only to be hurried down once more, as the water retires to allow another wave to do the same work.

236. By this continual up-and-down movement of the water, the sand and stones on the beach are kept grinding against each other, as in a mill. Consequently, they are gradually ground smooth and worn away. The stones become smaller, until they pass into mere sand, and the sand, growing finer, is swept away out to sea and laid down at the bottom.

237. But not only the loose materials on the

shore suffer in this way an incessant wear and tear: the solid rocks underneath, wherever they come to the surface, are ground down in the same process. When the waves dash against a cliff, they hurl the loose stones forward, and batter the rocks with them. Here and there, in some softer part, as in some crevice of the cliff, these stones gather together, and when the sea runs high, they are kept whirling and grinding at the base of the cliff, till, in the end, a cave is actually bored by the sea in the solid rock, very much in the same way as holes are bored by a river in the bed of its channel (Art. 179). The stones, of course, are ground to sand in the process, but their place is supplied by others swept up by the waves. If you enter one of these sea-caves when the water is low, you will see how smoothed and polished its sides and roof are, how well rounded and worn are the stones lying on its floor. And you may even notice bruises on the stones and on the walls, marking where the loose material has been hurled by the waves against the solid rock.

IV. The Bottom of the Sea.

238. So far as we know, the bottom of the sea is somewhat like parts of the surface of the land. It has heights and hollows, vast plains, lines of valleys, and ranges of hills. Though these cannot be seen by the eye, their existence and distribution are ascertained by means of a long line with a lead-weight or a dredge tied to the end of it. In this

way voyagers discover the depth of the water, and what is the nature of the bottom, whether rock or gravel, sand, mud, or shells. This measuring of the depths of the sea is called **Sounding.**

239. Soundings have been made over many parts of the sea, and much is now known about its depth and the nature of its bottom. The Atlantic Ocean, which has been particularly explored, has probably an average depth in its opener parts of from two to three and a half miles. Here and there are deep submarine hollows that sink below the average level. About 100 miles from the island of St. Thomas, for example, a sounding was obtained of nearly four miles and a half. If Mont Blanc, which is the highest mountain in Europe, reaching a height of 15,744 feet above the sea, could be set down in the deepest part of the Atlantic, it would not only sink out of sight, but its top would actually be nearly a mile and a half below the surface.

240. The average depth of the sea is probably rather more than two miles (2100 fathoms). But even in the midst of the oceans some parts of the bottom rise up to the surface and form islands. As a rule, water deepens towards mid-ocean, and shallows towards land. Hence those parts of the sea which run in among islands and promontories are, for the most part, comparatively shallow. Immediately in front of a continent the ocean-floor usually slopes gently under no more than about 100 fathoms of water for a variable distance from land, and then

plunges rapidly into deep water. This shallow rim or continental shelf is the great tract over which the detritus of the land is spread. In Europe it includes the basin of the North Sea, and stretches westward beyond the British Isles, which stand upon it. The North Sea never deepens much even over its middle parts, where there is nowhere a depth of so much as 400 feet. Some notion may be formed of the shallowness of the channel between England and France, from the statement that if St. Paul's Cathedral could be lifted from London, and set down in the middle of the Strait of Dover, more than a half of the building would be out of the water.

241. Not only have successful soundings been made of the deepest abysses of the sea, but by means of the **dredge** it has been possible to bring up bucketfuls of whatever may be lying on the sea-floor, even at the profoundest depths. In this way, a great deal of additional knowledge has recently been gathered as to the nature of the sea-floor, and the kinds of plants and animals which live there. Over wide spaces on the floor of the great ocean there is abundant animal life, such as shells, corals, star-fishes, and still more humble creatures.

242. In earlier parts of this book we have traced some of the changes which from day to day take place upon the surface of the land. Let us now try to realise some of those which must go on upon the floor of the sea. We cannot, indeed, examine the sea-bottom with anything like the same minuteness

as the surface of the land. Yet a great deal may be learnt regarding it.

243. Putting together some of the facts detailed in the foregoing Lessons, we may without difficulty understand some of the most important changes which are in progress on the floor of the sea. We have learnt what a prodigious amount of wasted rock is every year removed from the surface of the land and carried into the sea by streams (Art. 186). From the time when it is loosened from the sides of the mountains, hills, or valleys, this decomposed material is always seeking a lower level. On reaching the hollows of the sea-bottom it cannot descend any farther, but must necessarily accumulate there.

244. It is evident, then, that between the floor of the sea and the surface of the land there must be this great difference: that whereas the land, wherever exposed to the air, rain, frost, and the general decay that affects the surface (Arts. 133-158), is undergoing a continual destruction, from mountain-crest to sea-shore; the sea-bottom, on the other hand, is constantly receiving deposits of fresh materials. The one is increased in proportion as the other is diminished. So that even without knowing anything regarding what men have found out by means of deep soundings, we could confidently assert that every year there must be vast quantities of gravel, sand, and mud laid down upon the floor of the sea, because we know that these materials are worn away from the land.

245. Again, the restless agitation of the sea is caused by movements of the air, and the destruction which the sea can effect on the land is largely due to the action of waves raised by wind. But this action must be merely a surface one, and can only affect coast-lines and shallow parts of the sea-floor. The influence of the waves cannot reach to the bottom of the deep sea. Consequently that bottom lies beyond the reach of the various kinds of destruction which so alter the face of the land. The finer materials derived from the waste of the land and borne away by currents till they sink to the sea-bottom can lie there without further disturbance than they may suffer from the flow of such ocean-currents as touch the bottom.

246. In what way, then, are the gravel, sand, and mud disposed of when they reach the sea? As these materials are all brought from the land, they accumulate on those parts of the sea-floor which border the land, rather than at a distance. Banks of sand and gravel may be expected to occur in shallow seas and near land, but not in the middle of the ocean. Fine mud, on the other hand, may be transported for two hundred or three hundred miles from land before it finally subsides to the bottom.

247. We may form some notion, on a small scale, as to how the materials are arranged on the sea-bottom, by examining the channel of a river in a season of drought. At one place, where the current has been strong, there may be a bank of gravel; at

another place, where feebler currents of the river have met, we find, perhaps, a ridge of sand which they have heaped up; while in those places where the flow of the stream has been still more gentle, the channel may be covered with a layer of fine silt or mud.

248. A muddy river may be made to deposit its mud if its overflows it banks so far as to spread across flat land, for in so doing it has its flow checked (Art. 182). The more powerful a current of water, the larger are the stones it can move along. Hence, coarse gravel is not likely to be found over the bottom of the sea, except near the land, where the waves can sweep it out into the path of strong sea-currents, or in the track of icebergs, which sometimes bear earth and stones on their surface and drop them on the sea-floor as the ice melts. Sand will generally be carried farther out than gravel, and will be laid down in great sheets, or in banks. The finer mud and silt, though occasionally borne by currents for two hundred miles or more, probably, as a rule, settle on the sea-bottom before they have been carried more than forty or fifty miles from land.

249. The sand, mud, and gravel, worn from the land, are thus spread out in vast sheets and banks over that part of the bottom of the sea that lies near the land. But over by far the largest part of the sea-floor there can be little or no deposit of even the finest sediment borne from the land. Red and gray

clay, composed of volcanic detritus and possibly derived mainly from submarine volcanoes, covers vast spaces of the floor of mid-ocean.

250. But the sea is full of life, both of plants and animals. These organisms die, and their remains are necessarily mixed up with the different materials laid down upon the sea-floor. So that, besides sand, clay, and mud, great numbers of shells, corals, and

FIG. 18. – Island formed by the Growth of Coral.

the harder parts of other sea-creatures, must be buried there, as generation after generation lives and dies.

251. It often happens that on parts of the sea-bed the remains of some of these animals are so abundant as to form of themselves wide-spread accumulations. Oysters, for example, grow thickly together; and their shells, mingled with those of other similar creatures, form what are called **shell-banks**. In the Pacific and the Indian Oceans a little animal, called the coral-polyp, secretes a hard

limy skeleton from sea-water; and as millions of these polyps grow together, they form great **Coral-reefs**, which are solid limestone, sometimes, as in the Great Barrier Reef of Australia, hundreds of feet thick and a thousand miles long. It is by means of the growth of these animals that those wonderful rings of coral-rock or **Coral-islands** (Fig. 18) are formed in the middle of the ocean. Again, a great part of the bed of the Atlantic

FIG. 19.—Ooze from floor of Atlantic Ocean, consisting chiefly of Foraminifera; magnified 25 times.

Ocean is covered with fine ooze, which on examination is found to consist almost wholly of the remains of very minute animals called **Foraminifera** (Fig. 19).

252. Over the bottom of the sea, therefore, extensive and probably deep accumulations of sand and mud, mingled with the remains of plants and animals, have in the course of ages been formed, and are still continually being increased by fresh deposits. Were the ocean-floor to be raised up above the sea-level, and were its sand and mud to become as dry and hard as any rock among the hills,

it would nevertheless be possible to say with certainty that these materials had once been the bed of the sea, because they would be found to enclose the shells and other remains of creatures that could only have lived in the sea.

253. You will afterwards learn when you come to the science of Geology that this raising of the sea-bottom has often taken place in ancient times. You will find most of the rocks of our hills and valleys to have been originally laid down in the sea, where they were formed out of sand and mud dropped on the sea-floor, just as sand and mud are carried out to sea and laid down there now. And in these rocks, not merely near the shore, but far inland, in quarries or ravines, on the sides and even on the tops of hills, you will be able to pick out the skeletons and fragments of the various sea-creatures that lived in the old seas.

254. Since the bottom of the sea forms the great receptacle into which the mouldered remains of the surface of the land are continually carried, it is plain that if the present state of things were to go on without interruption, in the end the whole of the solid land would be worn away, and its remains would be spread out on the sea-floor, leaving one vast ocean to roll round the globe.

255. But there is in nature another force which here comes into play to retard the destruction of the land. In the remaining Lessons we shall inquire what this force is, and how it works.

THE INSIDE OF THE EARTH.

256 The foregoing pages have described the surface of the earth, and what goes on there. Let us now consider for a little what can be learnt regarding the inside of the earth. It may seem, at first, hardly possible that man should ever know anything about the earth's interior. Think what a huge ball this globe of ours is, and how, in living and moving over its surface, we are merely like flies walking over a great hill. All that can be seen from the top of the highest mountain to the bottom of the deepest mine is not more, in comparison with the size of the whole earth, than the mere varnish on the outside of a school-globe.

257. And yet a good deal may be learnt as to what takes place within the earth. Here and there, in different countries, there are places where communication exists between the interior and the surface; and it is from such places that much of our information on this subject is derived. **Volcanoes** or **Burning-mountains** (Fig. 20) are among the most important of these channels of communication.

258. Suppose you were to visit one of these volcanoes just before what is called an "eruption." From the distance it appears as a conical mountain with its top cut off. From this truncated summit a white cloud rises; but not quite such a cloud as may be seen on an ordinary hill-top. For after

watching it a little time, you would notice that it rises out of the top of the mountain, even when the sky is cloudless. Ascending from the vegetation of the lower grounds, you would find that the slopes consist partly of loose stones and ashes, partly of rough black sheets of rock, like the slags of an iron furnace. Nearer the top the ground feels hot, and

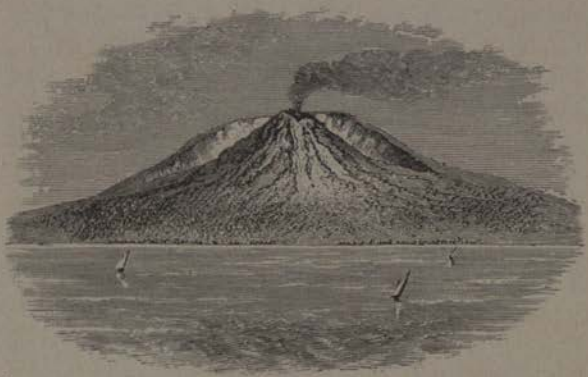

FIG. 20.—View of a Volcano. Mount Vesuvius as it appears at the present time when viewed from the south.

puffs of steam, together with stifling vapours, come out of it here and there. At last when the summit is reached, what seemed from below to be a level top is seen to be in reality a great basin, with steep walls descending into the depths of the mountain. Screening your face as well as possible from the hot gases which would almost choke you, you might creep to the edge of this basin and look down into

it. Far below, at the base of the rough red and yellow cliffs which form its sides, lies a pool of some liquid glowing with a white heat, though covered for the most part with a black crust like that seen on the outside of the mountain during the ascent. From this fiery pool jets of the red-hot liquid are jerked out every now and then, and harden into stone as they are cooled in the air. Showers of stones and dust are shot forth and fall back again into the caldron or down the outside of the mountain. Clouds of steam ascend from the same source to form the uprising cloud which is seen from a great distance, hanging over the mountain-top.

259. The caldron-shaped hollow on the summit of the mountain is called the **Crater.** The intensely heated liquid in the sputtering boiling pool at its bottom is melted rock or **Lava.** The fragmentary materials—ashes, dust, cinders, and stones—are torn from liquid lava or from the hardened sides and bottom of the crater by the violence of the explosions with which the gases and steam escape.

260. The hot air and steam, and the melted mass at the bottom of the crater, show that there must be some source of intense heat underneath. And as the heat has been coming out for hundreds or even thousands of years, it must exist there in great abundance.

261. But it is when the volcano appears in active eruption that the power of this underground

heat shows itself most markedly. For a day or two beforehand the ground around the mountain trembles. At length, in a series of violent explosions, the heart of the volcano is torn open, and perhaps its upper part is blown into the air. Huge clouds of steam roll away up for thousands of feet into the air, mingled with fine dust and red-

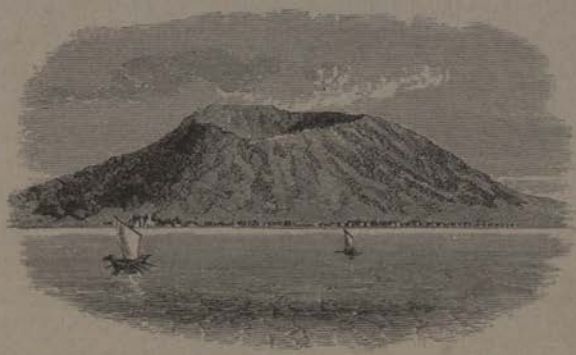

Fig. 21.—Vesuvius as it appeared before Pompeii was destroyed.

hot stones. The heavier stones fall back again into the crater, or on the outer slopes of the mountain, but the finer ashes come out in such quantity as sometimes to spread over the sky and make noonday as dark as midnight for many miles round. These ashes or dust partly settle down over the surrounding country as a thick covering and partly are carried away into other regions by upper currents of the atmosphere. Streams of molten lava run down the outside of the mountain,

and descend even to the gardens and houses at the base, burning up or overflowing whatever lies in their path. This state of matters continues for days or weeks, until the volcano exhausts itself, and then a time of comparative quiet comes when only steam, hot vapours, and gases are given off.

262. About 1800 years ago there was a mountain near Naples shaped like a volcano, and with a large crater covered with brushwood (Fig. 21). No one had ever seen any steam, or ashes, or lava come from it, and the people did not imagine it to be a volcano, like some other mountains in that part of Europe. They had built villages and towns around its base, and their district, from its beauty and soft climate, used to attract wealthy Romans to build villas there. But at last, after hardly any warning, the whole of the higher part of the mountain was blown into the air with terrific explosions. Such showers of fine ashes fell for miles around that the day was as dark as midnight. Day and night, the ashes and stones descended on the surrounding country; many of the inhabitants were killed, either by stones falling on them, or from suffocation by the dust. When at last the eruption ceased, the district, which had before drawn visitors from all parts of the Old World, was found to be a mere desert of gray dust and stones. Towns and villages, vineyards and gardens, were all buried. Of the towns, the two most noted, called Herculaneum and Pompeii, so

completely disappeared that, although important places at the time, their very sites were forgotten, and only by accident, after the lapse of some fifteen hundred years, were they discovered. Excavations have since that time been carried on, the hardened volcanic accumulations have been removed from the two old towns, and one can now walk through the streets of Pompeii again, with their roofless dwelling-houses and shops, theatres and temples, and mark on the causeway the deep ruts worn by the carriage wheels of the Pompeians eighteen centuries ago. Beyond the walls of the now silent city rises Mount Vesuvius, with its smoking crater, covering one-half of the old mountain which was blown up when Pompeii disappeared (see Fig. 20).

263. Volcanoes, then, mark the position of some of the holes or orifices, whereby heated materials from the inside of the earth are thrown up to the surface. They occur in all quarters of the globe. In Europe, besides Mount Vesuvius, which has been more or less active since its great eruption in the first century, Etna, Stromboli, Santorin, and other smaller volcanoes, occur in the basin of the Mediterranean; while far to the north-west, active volcanoes rise amid the snows and glaciers of Iceland. In South America a chain of huge volcanoes stretches down the range of the Andes, that rise near the western margin of the continent. In Asia, volcanoes are thickly grouped together in

Java and the surrounding islands, where in August 1883 there occurred at the island of Krakatoa the most stupendous volcanic eruption of recent times. From that district a line of active volcanoes stretches through Japan and the Aleutian Isles to the extremity of North America. Tracing this distribution upon the map, we observe that the Pacific Ocean is girdled round with volcanoes.

264. Since these openings into the interior of the earth are so numerous over the surface, we may conclude that the interior is intensely hot. But other proofs of this internal heat may be gathered. In many countries **hot springs** rise to the surface. In some volcanic districts hot water and steam gush out at intervals with great force into the air for a height of a hundred feet or more. Even in England, which is a long way from any active volcano, the water of the wells of Bath is quite warm (120° Fahr.). It is known, too, that in all countries the heat increases as we descend into the earth. The deeper a mine the warmer are the rocks and air at its bottom. If the heat continues to increase in the same proportion, the rocks must be red hot at no great distance beneath us. We must conclude, then, that this globe on which we live has a comparatively thin, cool outer shell or crust, within which the interior is intensely hot.

265. The explosions of a volcano shake the ground, sometimes with great violence. But the solid earth is affected by movements even remote from any

volcano. Very delicate instruments have revealed that though the ground beneath us seems to be perfectly steady, it is continually affected by slight tremors. When the movement becomes strong enough to be quite perceptible it is called an **Earthquake**, which may vary from a feeble, hardly sensible trembling of the ground up to a violent concussion, whereby the ground is convulsed and even rent open, trees, rocks, and buildings are thrown down, and sometimes thousands of people are killed. Earthquakes are more particularly frequent and destructive in mountainous regions, along ocean borders, and around active volcanoes.

266. Though earthquakes may destroy much life and property, they do not permanently alter the face of the globe so much as another kind of earth-movement of a much slower and less startling nature. Some parts of the land are slowly rising. When this upheaval takes place in maritime tracts, rocks that used always to be covered by the tides come to lie wholly beyond their limits; while others, once never to be seen at all, begin one by one to show their heads above water. On the other hand, some regions are slowly sinking; piers, sea-walls, and other old landmarks on the beach, are one after another enveloped by the sea as it encroaches farther and higher on the land.

267. Even at the present day, therefore, we know that one result of the movements of the outer part or crust of the earth is to raise some regions above

the level of the sea, and to increase the height of others that are already dry land. Reflecting on this process, we soon perceive that it must be by such elevations that dry land continues upon the face of the earth. If rain and frost, rivers, glaciers, and the sea, were continually and without check to wear down the surface of the land, that surface would necessarily in the end disappear, and indeed must have disappeared long ago. But, on the one hand, owing to the pushing out of some parts of the earth's surface from within, portions of the land are raised to a higher level, while parts of the bed of the sea are actually upheaved so as to form land. On the other hand, certain larger tracts, more particularly of the ocean-floor, sink inward; the ocean-basins are thus deepened, and in some measure the level of the sea is thereby lowered.

268. This kind of oscillation has happened many times in all quarters of the globe. As already mentioned (Art. 253), most of our hills and valleys are formed of rocks which were originally laid down on the bottom of the sea, and have been subsequently raised into land. In almost every country proofs may be found that the land has repeatedly been submerged and re-elevated.

CONCLUSION.

269. In conclusion, let us sum up the leading features of the foregoing Lessons.

The Earth is the scene of continual movement and change. The atmosphere that encircles it is ever in motion, diffusing heat, light, and vapour. From the sea and from the waters of the land, vapour is constantly passing into the air, whence, condensed into dew, clouds, rain, hail, and snow, it descends again to the earth. All over the surface of the land the water that falls from the sky courses seawards in brooks and rivers, bearing into the great deep the materials which are worn away from the land. Water is thus ceaselessly circulating between the air, the land, and the sea. The sea, too, is never at rest. Its waves gnaw the edges of the land, and its currents sweep round the globe and distribute climates. Into its depths the spoils of the land are borne, there to gather into rocks, out of which new islands and continents will eventually be formed. Lastly, while the outer layers of the earth are cool, the interior must be intensely hot. This internal heat manifests itself in a striking way at the surface in volcanoes and boiling springs. From time to time also the solid earth is convulsed with earthquakes. There are movements of a more tranquil kind whereby some tracts are upraised and others are depressed. Thus, while old land is submerged beneath the sea, new tracts are upheaved, to be clothed with vegetation and peopled with animals, and to form a fitting abode for man himself.

270. This world is not a living being, like a plant or an animal, and yet there is evidently a sense in

which we may speak of it as endowed with life. The circulation of air and water, the interchange of sea and land,—in short, the system of endless and continual movement by which the face of the globe is day by day altered and renewed,—may well be called the Life of the Earth.

QUESTIONS.

THE SHAPE OF THE EARTH, p. 9.

1. What were the notions that mankind in early times had about the shape of the Earth? and the relation of the Earth to the sun, moon, and stars?

2. How can we prove, in the middle of a level country, that the apparently flat plain is really part of the curved surface of a globe?

3. How can the same fact be proved on the sea?

4. How has the Earth been practically shown to be a globe by "circumnavigators"?

5. What relation do high mountains and deep valleys bear to the curvature of the Earth?

6. How does the gentle curvature of the Earth's surface indicate the size of the Globe?

7. How long would a railway train, moving at the rate of thirty miles an hour, take to go round the Earth?

8. What have astronomers discovered to be the actual shape of the Earth?

9. What is meant by the *Poles of the Earth?*

10. Explain what is meant by the *Polar Diameter* of the Earth, and state its length.

11. Define what is meant by the *Equator.*

12. What is the *Equatorial Diameter* of the Earth, and what is its length?

13. What is the difference between the length of the polar and equatorial diameters?

DAY AND NIGHT p. 15

1. Whence does our Earth receive its heat and light?

2. What was the early belief of mankind as to the position of the Earth, relative to sun, moon, and stars?

3. How is this ancient notion perpetuated in our every-day speech?

4. What is the real relation of the Earth to the Sun?

5. What is meant by the Rotation of the Earth?

6. Explain the meaning of *Axis of Rotation.*

7. Show how the rotation of the Earth may be explained by the use of a school globe and a lighted candle.

8. Explain what is meant by *North Pole* and *South Pole.*

9. Explain the cause of Day and Night.

10. How can it be shown in which direction the Earth is rotating, both by day and by night?

11. What determines the length of a Year?

12. Explain what is meant by the *Orbit* and the *Revolution of the Earth.*

13. How far is the Earth distant from the Sun?

14. How long does the Earth take to complete a revolution round its orbit?

15. What is the average rate at which the Earth is moving onward along its orbit?

16. Show how our divisions of time are marked out for us by the movements of the Earth.

THE AIR.

I. What the Air is made of, p. 19.

1. Mention some of the various conditions assumed by the Air.

2. Give a familiar illustration of the existence of the Air.

3. What is the Atmosphere? State its relation to the solid body of the Earth.

4. How deep is the Atmosphere believed to be?

5. What is the composition of Air?

6. Name some of the prevalent substances in the Air, besides the chief gases.

7. How may the presence of solid particles in the air be made visible?

8. What is Water-vapour? [see Art. 66]. Show by any familiar example how it is invisibly dissolved in the Air [Art. 64].

9. In what proportion does Carbonic Acid Gas occur in the Air?

10. How does this dissolved Carbonic Acid Gas in the Air influence Plants?

11. Mention some of the ways in which Carbonic Acid Gas is restored to the Air.

12. Describe the circulation of Carbonic Acid Gas between the Air and Plants and Animals.

II. The Warming and Cooling of the Air, p. 22.

1. Show how, though invisible, the Air, even when motionless, may make itself felt by us.

2. Why do we feel cold if we pass from a warm room into the outer Air in Winter?

3. How are changes of Temperature measured?

4. What is *Radiation?*

5. Whence does the Earth obtain its heat? And why are there variations in temperature from hour to hour?

6. What is the effect of the appearance of Clouds between the Earth and the Sun?

7. Why is the Sun's heat less felt in the morning and in the evening than at noon?

8. Why is Night colder than Day?

9. Why is Summer warmer than Winter?

10. Why is it that cloudy days are not always or necessarily cold?

11. Explain by a familiar example how heated bodies lose their heat. Show how this process takes place on the surface of the land.

12. What prevents excessive loss of heat at night by radiation?

13. Why are the nights often so cold in climates where the days may be exceedingly hot?

14. Why are cloudy nights usually less cold than clear nights?

15. What part is taken by the Atmosphere in the distribution of heat over the surface of the Globe?

III. The Vapour in the Air. Evaporation and Condensation, p. 28.

1. Explain why a film of mist appears on a cold glass when brought into a warm room, and on the inside of window-panes.

2. Explain the terms *Condensed* and *Condensation.*

3. How does the capacity of the Air to retain Water-vapour vary?

4. Why does a film of mist appear upon a mirror or other cold surface when it is breathed on, and what is the explanation of the cloud which issues from one's mouth with every breath in cold weather?

5. What is the Dew-point?

6. How is the Vapour of Water brought into the Air? Show how this may be experimentally illustrated.

7. What is meant by *Evaporation?*

8. At what times in the twenty-four hours is Evaporation most and least vigorous? Explain the reason of the difference.

9. Why may roads remain moist in cool, cloudy weather, yet dry up quickly when the sun shines on them?

10. Explain why Evaporation is less in damp than in dry weather, and illustrate the answer by a familiar example.

11. Explain the cause of the chill that is felt when a drop of water is evaporated on the back of the hand.

12. What has been estimated to be the amount of Water-vapour annually condensed upon the Earth's surface?

IV. Dew, Mist, Clouds, p. 33.

1. Give some examples of the Condensation of Water-vapour.

2. What happens when Water-vapour is first condensed?

3. What does the film consist of that appears upon a cold glass which is brought into a warm room?

4. Explain the formation of Dew.

5. Show how Mists are formed upon mountains.

6. Explain the origin of the Fog often seen after sunset rising from the surface of a River.

7. What are Clouds, and how are they formed?

8. Why do Clouds in warm weather often gather about midday and disappear again towards night?

9. How is it that Clouds often travel rapidly across the sky?

V. Rain and Snow, p. 37.

1. In what ways do Clouds disappear from the Sky?

2. Explain the formation and fall of Rain.

3. In what different conditions does the substance called Water exist?

4. What is Ice, and when is it formed?

5. What is meant by the Freezing-point?

6. Describe a Snowflake.

7. Why is a mass of Snow white?

8. What effect on temperature has elevation above the surface of the Earth?

9. Over what parts of the Earth does Snow chiefly fall and lie?

10. What are Hail and Sleet?

VI. The Movements of the Air, p. 40.

1. What evidence can be given of the continual movement of the Air?

2. Whether is warm or cold air the heavier, and why?

3. How does this difference in weight affect the movements of the Air? Illustrate the answer by an easy experiment.

4. On what principle are open fire-places constructed?

5. Is any of the heat of one of these fire-places lost to the room?

6. What are the different effects of an open fire-place and a close stove upon the ventilation of a room?

7. Show by any simple proof that the heat we feel in direct sunshine is not due to mere warmth of the Air.

8. Explain how the heating of the Earth's surface gives rise to Wind.

9. Describe Land- and Sea-breezes, and explain the cause of them.

10. How are the movements of the Air affected by Water-vapour?

11. What is meant by the *Pressure of the Atmosphere?*

12. Explain the use of the *Barometer.*

13. What is the law that governs the movement of the Air with regard to Atmospheric Pressure?

14. What is the origin of Storms and Hurricanes?

15. Where are the chief regions of high and low Atmospheric Pressure, and how do they affect the greater movements of the Atmosphere?

16. Why is the Rainfall especially copious in the equatorial regions?

17. Explain the origin of the *Trade Winds.*

18. State again the fundamental law according to which movements of the Atmosphere take place.

THE CIRCULATION OF WATER ON THE LAND, p. 46.

1. Whence does the Atmosphere receive its Water-vapour?

2. Into what visible forms is this vapour condensed?

3. Briefly describe the circulation of Water between the Atmosphere and the Earth, and mention some of its uses in the general life of the Globe.

I. What becomes of the Rain, p. 47.

1. Why do not seas, lakes, and rivers grow less from the abstraction of Water-vapour which they supply to the Atmosphere?

2. What part does the Sea play in supplying the Air with moisture?

3. What becomes of that part of the Rain which falls into the Sea?

4. What has been estimated to be the amount of Rain that falls in a year upon the British Isles?

5. Mention the annual Rainfall in some parts of India.

6. Describe what becomes of heavy rain that falls on a sloping road or field.

7. What proportion of the Rainfall is estimated to be discharged into the Sea? What becomes of the rest of it?

8. How may it be shown that a considerable quantity of rain sinks into the ground, and yet that this quantity is not permanently removed from the general circulation?

9. How is the Rain disposed of which falls on the surface of the land?

II. How Springs are formed, p. 51.

1. How do soils and rocks differ from each other in respect to the passage of water through them?

2. Explain what is meant by a *pervious* and an *impervious* Soil or Rock.

3. How does a bed of clay act in regard to the underground flow of water?

4. Explain the difference between sandy soils and clayey soils with regard to moisture.

5. What inference as to the movement of underground water may be drawn from the fact that water gathers in any deep hole or quarry which may be made in the ground?

6. What is meant by the *joints* of rocks, and how do they act in underground drainage?

7. Explain the cause of boggy places in hilly ground.

8. What are Springs?

9. Explain the cause of the outflow of Springs where two different kinds of stone meet along the side of a valley.

10. What are *Stratified* and *Unstratified* Rocks?

11. Explain the origin of deep-seated Springs.

12. How is the underground Circulation of Water shown by Wells, Mines, Pits, and Quarries?

III. The work of Water under ground, p. 57.

1. What is chemically pure water, and how may it be proved that the water of even the most limpid spring contains something more than pure water?

2. Mention any familiar solutions which show that clear, transparent water may contain a good deal of foreign matter invisible to the eye.

3. Whence must the substances dissolved in Spring-water be derived?

4. What is the action of Rain on Soils?

5. What does Rain remove from the Air?

6. When a small quantity of the rain that falls in a populous town is evaporated, what is left behind?

7. Whence does Rain-water derive the Carbonic Acid with which it descends into underground rocks?

8. Describe the effect of water containing Carbonic Acid upon many Rocks.

9. What is meant by *hard* water and *soft* water?

10. Mention some of the advantages to plants and animals of the mineral substances contained in solution in Spring-water.

11. Explain how underground caverns and tunnels are formed.

IV. How the Surface of the Earth crumbles away, p. 62.

1. What happens to surfaces of masonry after long exposure to the air?

2. How is the same change shown in exposed marble tombs and monuments?

3. Show how the change may be observed elsewhere than in structures erected by man.

4. Explain the part taken by Carbonic Acid and Organic Acids in the crumbling of rocks on the surface of the land.

5. What is Rust?

6. Explain the action of Oxygen in Rain-water in the decay of rocks.

7. Why are jugs of water often split open during a severe winter?

8. Explain the action of Frost upon Soils and Rocks.

9. How does Frost help the work of the farmer?

10. In what way do the Joints of rocks contribute to the effects of Frost?

11. Explain how columns and pinnacles of rock may be left standing by the working of Frost.

12. What is the effect of rapidly recurring extremes of heat and cold upon the surfaces of rocks?

13. How does Wind promote the wearing down of rocks?

14. Give an account of the various processes of decay which are included under the general term *Weathering*.

15. State the general result of the co-operation of all these forces.

V. What becomes of the Crumbled Parts of Rocks. How Soil is made, p. 71.

1. Of what is common garden Soil made?

2. Is any actual disappearance of material from the Earth brought about by what we call the "decay" or "waste" of the land?

3. What is meant by the Chemical Action of Rain?

4. Explain the Mechanical Action of Rain.

5. What becomes of the loose crumbled particles of rocks carried onward by rain-water upon the surface of the land?

6. What is the origin of the mud, sand, and gravel of rivers and the sea-coast?

7. How is Soil made, and why does the soil of one place differ from that of another place?

8. Explain how Soil is continually renewed.

9. In what ways do Plants contribute to the formation of Soil?

10. What part is taken by Earth-worms in the production of Soil?

11. In what sense may it be said that the whole surface of the Land is travelling towards the Sea?

12. How do Brooks exemplify the reality and extent of the mouldering of the surface of the Land?

VI. Brooks and Rivers: Their Origin, p. 76.

1. Describe the formation of miniature Brooks and Rivers on a sloping roadway during a heavy shower of Rain.
2. Why do Streams flow?
3. What are Lakes?
4. Why does not Rain, which may fall evenly upon a country, flow evenly over its surface?
5. What is the origin of the Brooks and Rivers of a country?
6. How are the innumerable brooks of the high grounds disposed of as they descend towards the lower country?
7. Why are the lower grounds not inundated by the union of the multitude of these brooks?
8. What is meant by a Watershed or Divide? Give examples.
9. Why do Brooks and Rivers continue to flow even in dry weather?
10. Why do small streams often dry up in summer?
11. Why are rivers in some countries more swollen in summer than in winter?
12. Give a brief account of the Circulation of Water over the Globe.

VII. Brooks and Rivers: Their Work, p. 83.

1. Give an illustration of the vast amount of mineral matter carried in chemical solution by a River to the Sea.
2. Describe the transport of sediment by a flooded river.
3. What evidence is there that rivers wear down the rocks of their channels?
4. Why are the stones in a water-course usually rounded?
5. Describe the channel of a stream in a time of drought [Arts. 178, 181].
6. What are Pot-holes?

7. Show what results from the constant rolling of rocks and stones along the bed of a stream.

8. What is the origin of the flat Terraces bordering a river?

9. Is there any permanent resting of the sediment in the bed or on the terraces of a river?

10. What happens to the sediment transported by a river when the stream enters a lake or the sea?

11. Describe a Delta, and show how it may be formed in a lake or in the sea.

12. Give an example of a large Delta.

13. What becomes of the mud and sand carried beyond the Delta?

14. What part is taken by the Sea in regard to the material worn away from the surface of the Land?

VIII. Snowfields and Glaciers, p. 91.

1. Mention some mountains where snow lies deep in winter, but disappears wholly, or nearly so, in summer.

2. Give examples of mountains of which the tops retain their snow all the year.

3. What is the nature of the climate of the Poles?

4. What is meant by the *Snow-line?*

5. Mention the elevation of the Snow-line in the equatorial regions and in polar latitudes.

6. Why does Snow remain perpetual above the Snow-line?

7. Contrast a Rainstorm and a Snowstorm.

8. What becomes of Snow below the Snow-line?

9. What is meant by a Thaw?

10. How does a rapid Thaw affect Brooks and Rivers?

11. Is Snow subject to evaporation?

12. In what manner is the surplus Snowfall above the Snow-line disposed of?

13. Describe the origin and appearance of a Glacier.

14. Where does a Glacier end in its valley?

15. Contrast the action of a Glacier with that of a river in the transport of sand, gravel, and stones.

16. What are Crevasses in a Glacier?

17. How do stones and earth find their way from the surface to the bottom of a Glacier ?

18. What use does a Glacier make of the sand and stones which it presses forward along its rocky bed ?

19. Why is the River muddy which escapes from the end of the clear ice of a Glacier ?

20. How is the rubbish of earth and stones disposed of which accumulates on the surface of a Glacier ?

21. What are Moraines ?

22. Give an example of the great size of some of the masses of rock which have been transported by glaciers for many miles in Switzerland.

23. Where are the largest Glaciers found ?

24. Explain the formation of Icebergs.

25. What proportion of an Iceberg rises above the level of the sea ?

26. What proofs have been found that glaciers once existed in countries where there is no longer perpetual snow ?

27. Mention some of the countries where these proofs have been gathered.

28. In what way does Snow exercise a beneficial effect on the surface of the ground ?

29. What are Avalanches ?

THE SEA.

I. Grouping of Sea and Land. General Features of the Sea, p. 104.

1. What are the proportions of Land and Water on the Earth's surface, and how have they been ascertained ?

2. Mention a broad distinction between the distribution of the Sea and that of the Land over the surface of the Globe.

3. What is meant by the Land-hemisphere and Water-hemisphere ?

4. What are Continents and Islands ?

5. What are Oceans ?

6. What is meant by the Horizon ?

7. In what respect does the water of the Sea differ from that of ordinary springs and rivers?

II. Why the Sea is Salt, p. 109.

1. What is believed to have been the original condition of the Globe?
2. What has been the probable origin of the Atmosphere?
3. How are the Oceans supposed to have arisen?
4. Whence has the Sea derived its Salts?
5. On what grounds may it be inferred that the water of the Sea is slowly becoming salter?
6. What is the relative saltness of the Atlantic Ocean and of the Dead Sea?

III. The Motions of the Sea, p. 111.

1. Describe the general characteristic of the surface of the Sea.
2. What is meant by the *Tides?*
3. What is *Surface-drift*, and how has its existence and direction been proved?
4. What are *Sea-currents*, and how is their motion sometimes revealed by Icebergs?
5. What influence have Currents upon climate? Contrast the climates of Labrador and North-west Europe, and explain the cause of the difference between them.
6. Mention the different motions of the Sea.
7. What is the origin of Waves?
8. What is the origin of *Ground-swell?*
9. What general effect have Waves upon a coast-line?
10. Describe the action of the Sea upon a rocky coast.
11. Mention the effect of the Sea on some parts of the coast of the east of England.
12. Why is the rate of waste comparatively small along the west coast of Scotland and Ireland?
13. Describe the action of the Waves in the wasting of a coast-line.
14. How does the sea excavate caves on a rocky shore?
15. What effect has wave-action upon the gravel of a beach?

IV. The Bottom of the Sea, p. 117.

1. What is the general character of the Sea-floor?

2. How has our information regarding the Bottom of the Deep Sea been obtained?

3. State some facts that have been ascertained regarding the depth of the Atlantic Ocean.

4. What is the difference between the height of Mont Blanc and the depth of the deepest part of the Atlantic?

5. State the average depth of the Sea.

6. Which are usually the deepest and which the shallowest parts of the Sea?

7. What is the general character of the sea-bottom in front of a Continent?

8. Where is most of the detritus of the land deposited?

9. Describe the Continental Shelf of Western Europe.

10. What is the depth of the North Sea?

11. How much of St. Paul's Cathedral in London would be submerged if it were set down in the middle of the Strait of Dover?

12. By what means have we gained knowledge of what is lying on the floor of the deepest abysses of the Ocean?

13. What has the Dredge revealed as to the life of the Deep Sea?

14. What broad distinction may be drawn between the surface of the land and the floor of the Sea?

15. To what part of the Sea is the destructive action of Waves limited?

16. Why must we believe the bottom of the Deep Sea to remain undisturbed?

17. Where may banks of Sand and Gravel be expected to be formed?

18. What becomes of the fine Mud carried by rivers into the Sea?

19. Within what average distance from Shore does the finer sediment derived from the land sink to the bottom of the Sea?

20. What is the nature of the Deposits on the Ocean floor at great distances from land?

21. What becomes of the remains of the living creatures on the Sea-bottom?

22. What are Shell-banks?

23. Describe the formation of Coral-reefs and Coral-islands.

24. What is the nature of the Ooze which covers a great part of the bed of the Atlantic Ocean?

25. How can it be affirmed with certainty that some rocks have been formed under the Sea?

26. What would be the result of the continual waste of the Land if there were no compensating force at work?

THE INSIDE OF THE EARTH, p. 126.

1. Does the distance from the top of the highest mountain to the bottom of the deepest mine bear a large proportion to the diameter of the whole Globe?

2. What is a Volcano?

3. Describe a Crater.

4. What is Lava?

5. What various materials are thrown out by a Volcano?

6. What evidence do these materials furnish as to the condition of the Earth's Interior?

7. Give some account of a Volcanic Eruption.

8. What has been the history of Mount Vesuvius?

9. State the position of some of the Volcanoes of Europe America, and Asia.

10. What inference may be deduced from Volcanoes as to the temperature of the Earth's Interior?

11. What evidence is furnished by Hot Springs?

12. What has been observed regarding Temperature when borings have been made into the Earth, and what conclusion has been drawn from it?

13. Is the Land really as solid as it is commonly believed to be?

14. What is an Earthquake?

15. Where are Earthquakes most frequent?

16. What evidence has been gathered to show that some

parts of the land are gradually rising above the sea, and that other parts are subsiding below it?

17. How is the wearing down of the land compensated?

18. Under what conditions were the rocks of most of the hills and valleys formed?

THE END.

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